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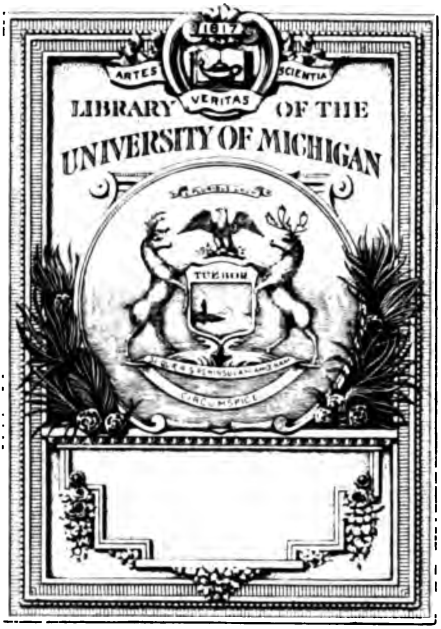
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GEOLOGICAL SURVEY OF ALABAMA

EUGENE ALLEN SMITH, STATE GEOLOGIST.

BULLETIN No. 8.

The Materials and Manufacture of Portland Cement.

BY

EDWIN C. ECKEL.

The Cement Resources of Alabama.

BY

EUGENE A. SMITH.

MONTGOMERY, ALABAMA
THE BROWN PRINTING COMPANY, PRINTERS AND BINDERS
1904

To His Excellency, Gov. R. M. Cunningham:

Sir: I have the honor to submit herewith Bulletin No. 8, on the Cement Resources of Alabama; with Preliminary Chapters on the Materials and Manufacture of Portland Cement, by Mr. Edwin C. Eckel, of the United States Geological Survey.

That part of the Report relating specially to the Alabama occurrences was prepared by the writer in coöperation with the United States Geological Survey, and in slightly different form, has been published in Bulletin No. 225, of that Survey. The chapters by Mr. Eckel, which add so much to the value and completeness of the Bulletin, have been generously contributed by him.

Our indebtedness to Senator John T. Morgan is particularly great, since the investigations on which this report is based, were undertaken mainly at his instance, and the coöperation above mentioned, secured through his influence.

Very respectfully,

Eugene A. Smith,
State Geologist.

University of Alabama,
July 1, 1904.

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LAUDERDALE
Florence
Sheffield
Tuscumbia
COLBERT
LAWREN
FRANKLIN
MARION
Hamilton
WINST
LAMAR
Vernon
FAYETTE
PICKENS
Carrollton
TUSCALOOSA
Tuscaloosa
GREENE
Eutaw
HALE
Greensboro
SUMTER
Livingston
Demopolis
MARENGO

PART I.

THE MATERIALS AND MANUFACTURE OF PORTLAND CEMENT.*

BY EDWIN C. ECKEL.

[The following paper on the raw materials and methods of manufacture of Portland Cement has been prepared as the result of field work and other investigations carried out by the writer for the United States Geological Survey. Certain sections of the contribution have appeared, in slightly different form, in *Municipal Engineering* during the past two years.]

CHAPTER 1.

THE RELATION OF PORTLAND TO OTHER CEMENTS.

It seems desirable, before taking up the specific subject of Portland cement, to indicate the relationships existing between Portland and other cementing materials. These relationships, both as regards resemblances and differences, seem to be best brought out by the classification presented below. This grouping is based primarily upon the amount of chemical change caused by the process of manufacture and use; and secondarily upon the chemical composition of the cement after setting. As regard is paid to both technologic and commercial considerations, it would seem to be a fairly satisfactory working classification.

GROUP I.—SIMPLE CEMENTS: Including all those cementing materials produced by the expulsion of a liquid or gas from the raw material; and whose setting properties are due to the simple reabsorption of the same liquid or gas and the reassumption of original composition; the set cement being therefore similar in composition to the raw material.

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Sub-group Ia. Hydrate Cements: Setting properties due to reabsorption of water.

Sub-group Ib. Carbonate Cements: Setting properties due to reabsorption of carbon dioxide.

GROUP II.—COMPLEX CEMENTS: Including all those cementing materials whose setting properties are due to the action of entirely new chemical compounds which were formed during manufacture or use; the set cement being therefore different in composition from the raw material.

Sub-group Ia. Silicate Cements: Setting properties due largely to the formation of silicates.

Sub-group IIb. Oxychloride Cements: Setting properties due to the formation of oxychlorides.

GROUP I—SIMPLE CEMENTS.

The cementing materials included in the present group are those known commercially as "plasters," "hard-finishing cements," and "limes."

The material from which the "plasters" and "hard-finishing cements" are derived is gypsum, a hydrous calcium sulphate; while the limes are derived from limestone, which is essentially calcium carbonate, though usually accompanied by greater or less amounts of magnesium carbonate.

On heating gypsum to a certain temperature, the raw material parts readily with much of its water, leaving an almost anhydrous calcium sulphate, known commercially as plaster-of-Paris. On exposing this plaster to water, it re-hydrates, and again takes the composition of the gypsum from which it was derived.

In like manner limestone, on being sufficiently heated, gives off its carbon dioxide, leaving calcium oxide or "quicklime." This, on exposure to moisture and air carrying carbon dioxide, reabsorbs carbon dioxide and reassumes its original composition, calcium carbonate.

The cementing materials included in this group, therefore, while differing in composition and properties, agree in certain important points. They are all manufactured by heating a natural raw material sufficiently to remove much or all of its water or carbon dioxide; and, in all, the setting properties of the cementing material are due to the fact that, on exposure to the water or carbon dioxide which has thus been driven off, the cement reabsorbs the previously expelled liquid or gas, and reassumes the chemical composition of the raw material from which it was derived.

Plaster-of-Paris, after setting, is not chemically different from the gypsum from which it was derived; while if the sand, added to avoid shrinkage, be disregarded, hardened lime mortar is nothing more or less than an artificial limestone.

Sub-group Ia. Hydrate Cements.

The materials here included are known in commerce as "plaster-of-Paris," "cement plaster," "Keene's cement," "Parian cement," etc. All of these hydrate cements are based upon one raw material,—gypsum. The partial dehydration of pure gypsum produces plaster-of-Paris. By the addition of gypsum, either by nature or during manufacture, of relatively small amounts of other materials; or by slight variations in the processes of manufacture, the time of setting, hardness, and other important technical properties of the resulting plaster can be changed to a sufficient degree to warrant separate naming and descriptions of the products.

Both the technology and the chemistry of the processes involved in the manufacture of the hydrate cements are simple. The mineral gypsum, when pure, is a hydrous sulphate of lime, of the formula $CaSO_4, 2H_2O$, corresponding to the composition calcium sulphate 79.1%, water 20.9%. Gypsum, as mined, rarely even approximates to this ideal composition, its impurities often amounting to 25% or even more. These impurities, chiefly clayey materials and fragments of quartz and limestone, often exercise an appreciable effect upon the properties of the plaster resulting from burning such impure gypsum.

On burning pure gypsum at a relatively low temperature (350°-400° F.) much of its water of combination is driven off, leaving a partially dehydrated lime sulphate. This, when ground, is plaster of Paris, or if it either naturally or artificially contains certain impurities, it is called "cement plaster." When either plaster of Paris or cement plaster are mixed with water, the percentage of water which was driven off during calcination is reabsorbed, and the mixture hardens, having again becomes a hydrous sulphate of lime. The processes involved in the manufacture and setting of the dead-burned plasters and hard-finish plasters are slightly more complicated, but the reactions involved are of the same general type.

Sub-group Ib. Carbonate Cements.

The cementing materials falling in the present sub-group are oxides, derived from natural carbonates by the application of heat. On exposure, under proper conditions, to any source of carbon dioxide, the cementing material recorbonates and "sets." In practice the carbon dioxide required for setting is obtained simply by exposure of the mortar to the air. In consequence the set of these carbonate cements, as commonly used, is very slow (owing to the small amount of carbon dioxide which can be taken up from ordinary air); and, what is more important from an engineering point of view, none of the mortar in the interior of a wall ever acquires hardness, as only the exposed portions have an opportunity to absorb carbon dioxide. From the examination of old mortars it has been thought probable that a certain amount of chemical action takes place between the sand and the lime, resulting in the formation of lime silicates; but this effect is slight and of little engineering importance compared with the hardening which occurs in consequence of the reabsorption of carbon dioxide from the air.

Limestone is the natural raw material whose calcination furnishes the cementing materials of this group. If the limestone be an almost pure calcium carbonate it will, on calcination, yield calcium oxide or "quicklime." If, however, the limestone should contain any appreciable percentage of magnesium carbonate, the product will be a mixture of the oxides of calcium and magnesium commercially known as magnesian lime. A brief sketch of the mineralogic relationships of the various kinds of limestone, in connection with the chemistry of lime-burning, will be of service at this point of the discussion.

Pure limestone has the composition of the mineral calcite, whose formula is $CaCO_3$, corresponding to the composition calcium oxide 56%, carbon dioxide, 44%. In the magnesian limestones part of this calcium carbonate is replaced by magnesium carbonate, the resulting rock therefore having a formula of the type X $CaCO_3$, Y $MgCO_3$. This replacement may reach the point at which the rock has the composition of the mineral dolomite—an equal mixture of the two carbonates, with the formula $CaCO_3$. $MgCO_3$, corresponding to the composition calcium oxide 30.43%, magnesium oxide, 21.74%, carbon dioxide, 47.83%. Limestones may therefore occur with any intermediate amount of magnesium carbonate, and the lime which they produce on calcination will carry corresponding percentages of magnesium oxide, from 0% to 21.74%. Commercially those limes which carry less than 10% of magnesium oxide are, for building purposes, marketable as "pure limes"; while those carrying more than that percentage will show sufficiently different properties to necessitate being marketed as "magnesian limes."

Aside from the question of magnesia, a limestone may contain a greater or lesser amount of impurities. Of these the most important are silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3). These impurities, if present in sufficient quantity, will materially affect the properties of the lime produced, as will be noted under the heads of Hydraulic Limes and Natural Cements.

The Carbonate Cements may be divided into two classes:—

(1) High calcium limes;

(2) Magnesian limes.

High Calcium Limes.—On heating a relatively pure carbonate of lime to a sufficiently high degree, its carbon dioxide is driven off, leaving calcium oxide (CaO) or "quicklime." Under ordinary conditions, the expulsion of the carbon dioxide is not perfectly effected until a temperature of 925° C. is reached. The process is greatly facilitated by blowing air through the kiln, or by the injection of steam. On treating quicklime with water, "slacking" occurs, heat being given off, and the hydrated calcium oxide (CaH_2O_2) being formed. The hydrated oxide will, upon exposure to the atmosphere, slowly reabsorb sufficient carbon dioxide to reassume its original composition as lime carbonate. As this reabsorption can take place only at points where the mortar is exposed to the air, the material in the middle of thick walls never becomes recarbonated. In order to counteract the shrinkage which would otherwise take place during the drying of the mortar, sand is invariably added in the preparation of lime mortars, and as noted above, it is probable that certain reactions take place between the lime and the sand. Such reactions, however, though possibly contributing somewhat to the hardness of old mortars, are only incidental and subsidiary to the principal cause of setting,—recarbonation. The presence of impurities in the original limestone affects the character and value of the lime produced. Of these impurities, the presence of silica and alumina in sufficient quantities will give hydraulic properties to the resulting limes; such materials will be discussed in the next group as Hydraulic Limes and Natural Cements.

Magnesian Limes.—The presence of any considerable amount of magnesium carbonate in the limestone from which a lime is obtained has a noticeable effect upon the character of the product. If burned at the temperature usual for a pure limestone, magnesian limestones give a lime which slakes slowly without evolving much heat, expands less in slaking, and sets more rapidly than pure lime. To this class belongs the well known and much used limes of Canaan (Conn.); Tuckahoe, Pleasantville and Ossining, (N. Y.); various localities in New Jersey and Ohio; Cedar Hollow (Penn.), and Chewacla (Ala.) Under certain conditions of burning, pure magnesian limestone yields hydraulic products, but in this case, as in the case of the product obtained by burning pure magnesite, the set seems to be due to the formation of a hydroxide rather than of a carbonate. Magnesian limestones carrying sufficient silica and alumina will give, on burning, a hydraulic cement falling in the next group under the head of Natural Cements.

GROUP II.—COMPLEX CEMENTS.

The cementing materials grouped here as Silicate or Hydraulic Cements, include all those materials whose setting properties are due to the formation of new compounds, during manufacture or use, and not to the mere reassumption of the original composition of the material from which the cement was made. These new compounds may be formed either by chemical change during manufacture or by chemical interaction, in use, of materials which have merely been mechanically mixed during manufacture.

In the class of silicate cements are included all the materials commonly known as cements by the engineer (natural cements, Portland cement, pozzuolanic cements), together with the hydraulic limes.

Though differing widely in raw material, methods of manufacture and properties, the silicate cements agree in two prominent features: they are all hydraulic (though in very different degrees); and this property of hydraulicity is, in all, due largely or entirely to the formation of tri-calcic silicate (3 CaO SiO_2). Other silicates of lime, as well as silico-aluminates, may also be formed; but they are relatively unimportant, except in certain of the natural cements and hydraulic limes where the lime-aluminates may be of greater importance than is here indicated. This will be recurred to in discussing the groups named.

The silicate cements are divisible, on technologic grounds, into four distinct classes. The basis for this division is given below. It will be seen that the first named of these classes (the pozzuolanic cements) differs from the other three very markedly inasmuch as its raw materials are not calcined after mixture; while in the last three classes the raw materials are invariably calcined after mixture. The four classes differ somewhat in composition, but more markedly in methods of manufacture and in the properties of the finished cements.

Classes of Silicate Cements.

1. Pozzuolanic Cements*: Produced by the mechanical mixture, without calcination, of slaked lime and a silico-aluminous material (the latter being usually a volcanic ash or blast-furnace slag.)

2. Hydraulic Limes: Produced by the calcination, at a temperature not much higher than that of decarbonation, of a siliceous limestone so high in lime carbonate that a considerable amount of free lime appears in the finished product.

---

*Also written Puzzolan.

3. Natural Cements: Produced by the calcination, at a temperature between those of decarbonation and clinkering, of a siliceous limestone (which may also carry notable amounts of alumina and of magnesium carbonate) in which the lime carbonate is so low, relatively to the silica and alumina, that little or no free lime appears in the cement.

4. Portland Cements: Produced by the calcination, at the temperature of semi-vitrefaction ("clinkering") of an artificial mixture of calcareous with silico-aluminous materials, in the proportion of about three parts of lime carbonate to one part of clayey material.

NATURAL CEMENTS.

Natural cements are produced by burning a naturally impure limestone, containing from 15 to 40 per cent. of silica, alumina, and iron oxide. This burning takes place at a comparatively low temperature, about that of ordinary lime burning. The operation can therefore be carried on in a kiln closely resembling an ordinary lime kiln. During the burning the carbon dioxide of the limestone is almost entirely driven off, and the lime combines with the silica, alumina, and iron oxide, forming a mass containing silicates, aluminates, and ferrites of lime. In case the original limestone contained much magnesium carbonate, the burned rock will also contain a corresponding amount of magnesia and magnesian compounds.

After burning, the burned mass will not slack if water be added. It is necessary, therefore, to grind it quite finely. After grinding, if the resulting powder (-natural cement) be mixed with water it will harden rapidly. This hardening or setting will also take place under water. The natural cements differ from ordinary limes in two noticeable ways:

(1) The burned mass does not slack on the addition of water.

(2) After grinding, the powder has hydraulic properties, *i. e.*, if properly prepared, it will set under water.

Natural cements are quite closely related to both hydraulic limes on the one hand, and Portland cement on the other, agreeing with both in the possession of hydraulic properties. They differ from hydraulic limes, however, in that the burned natural cement rock will not slake when water is poured on it.

The natural cements differ from Portland cements in the following important particulars:

(1) Natural cements are not made by burning carefully prepared and finely ground artificial mixtures, but by burning masses of natural rock.

(2) Natural cements, after burning and grinding, are usually yellow to brown in color and light in weight, their specific gravity being about 2.7 to 2.9; while Portland cement is commonly blue to gray in color and heavier, its specific gravity ranging from 3.0 to 3.2.

(3) Natural cements are always burned at a lower temperature than Portland, and commonly at a *much* lower temperature, the mass of rock in the kiln never being heated high enough to even approach the fusing or clinkering point.

(4) In use, natural cements set more rapidly than Portland cement, but do not attain such a high ultimate strength.

(5) In composition, while Portland cement is a definite product whose percentages of lime, silica, alumina and iron oxide vary only between narrow limits, various brands of natural cements will show very great differences in composition.

The material utilized for natural cement manufacture is invariably a clayey limestone, carrying from 13 to 35 per cent. of clayey material, of which 10 to 22 per cent. or so is silica, while alumina and iron oxide together may vary from 4 to 16 per cent. It is the presence of these clayey materials which give the resulting cement its hydraulic properties. Stress is often carelessly or ignorantly laid on the fact that many of our best known natural cements carry large percentages of magnesia, but it should, at this date, be realized that magnesia (*in natural cements at least*) may be regarded as being almost exactly interchangeable with lime, so far as the hydraulic properties of the product are concerned. The presence of magnesium carbonate in a natural cement rock is then merely incidental, while the silica, alumina and iron oxide are essential. The 30 per cent. or so of magnesium carbonate which occurs in the cement rock of the Rosendale District, N. Y., could be replaced by an equal amount of lime carbonate, and the burnt stone would still give a hydraulic product. If, however, the clayey portion (silica, alumina, and iron oxide) of the Rosendale rock could be removed, leaving only the magnesium and lime carbonates, the burnt rock would lose all of its hydraulic properties and would yield simply a magnesian lime.

This point has been emphasized because many writers on the subject have either explicitly stated or implied that it is the magnesian carbonate of the Rosendale, Akron, Louisville, Utica, and Milwaukee rocks that causes them to yield a natural cement on burning.

PORTLAND CEMENT.

Portland cement is produced by burning a finely ground artificial mixture containing essentially lime, silica, alumina, and iron oxide, in certain definite proportions. Usually this combination is made by mixing limestone or marl with clay or shale, in which case about three times as much of the lime carbonate should be present in the mixture as of the clayey materials. The burning takes place at a high temperature, approaching 3,000° F., and must, therefore, be carried on in kilns of special design and lining. During the burning, combination of the lime with silica, alumina, and iron oxide takes place. The product of the burning is a semi-fused mass called clinker, and consisting of silicates, aluminates, and ferrites of lime in certain definite proportions. This clinker must be finely ground. After such grinding the powder (—Portland cement) will set under water.

As noted above, under the head of Natural Cements, Portland cement is blue to gray in color, with a specific gravity of 3.0 to 3.2, and sets more slowly than natural cements, but soon attains a higher tensile strength.

PUZZOLAN CEMENTS.

The cementing materials included under this name are made by mixing powdered slaked lime with either a volcanic ash or a blast-furnace slag. The product is therefore simply a mechanical mixture of two ingredients, as the mixture is not burned at any stage of the process. After mixing, the mixture is finely ground. The resulting powder (Puzzolan cement) will set under water.

Puzzolan cements are usually light bluish to light yellow in color, and of lower specific gravity and less tensile strength than Portland cement. They are better adapted to use under water than to use in air.

CHAPTER 2.

PORTLAND CEMENT: DEFINITION, COMPOSITION AND CONSTITUTION.

In the following section various possible raw materials for Portland cement manufacture will be taken up, and their relative suitability for such use will be discussed. In order that the statements there made may be clearly understood, it will be necessary to preface this discussion by a brief explanation regarding the composition and constitution of Portland cement.

Use of term Portland.—While there is a general agreement of opinion as to what is understood by the term Portland cement, a few points of importance are still open questions. The definitions of the term given in specifications are in consequence often vague and unsatisfactory.

It is agreed that the cement mixture must consist essentially of lime, silica, and alumina in proportions which can vary but slightly; and that this mixture must be burned at a temperature which will give a semi-fused product—a "clinker." These points must therefore be included in any satisfactory definition. The point regarding which there is a difference of opinion is whether or not cements made by burning a natural rock can be considered true Portlands. The question as to whether the definition of Portland cement should be drawn so as to include or exclude such products is evidently largely a matter of convention; but, unlike most conventional issues, the decision has very important practical consequences. The question at issue may be stated as follows:

If we make artificial mixture of the raw materials and a very high degree of burning the criteria on which to base our definition, we must in consequence of that decision exclude from the class of Portland cements certain well known products, manufactured at several points in France and Belgium by burning a natural rock, without artificial mixture, and at a considerably lower temperature than is attained in ordinary Portland cement practice. These "natural Portlands" of France and Belgium have always been considered Portland cements by the most critical authorities, though all agree that they are not particularly *high grade* Portlands. So that a definition, based upon the criteria above named, will of necessity exclude from our class of Portland cements some very meritorious products.

There is no doubt that in theory a rock could occur, containing lime, silica, and alumina in such correct proportions as to give a good Portland cement on burning. Actually, however, such a perfect cement rock is of extremely rare occurrence. As above stated, certain brands of French and Belgian "Portland" cements are made from such natural rocks, without the addition of any other material; but these brands are not particularly high grade, and in the better Belgian cements the composition is corrected by the addition of other materials to the cement rock, before burning.

The following definition of Portland cement is of importance because of the large amount of cement which will be accepted annually under the specifications* in which it occurs. It is also of interest as being the nearest approach to an official government definition of the material that we have in this country:

"By a Portland cement is meant the product obtained from the heating or calcining up to incipient fusion of intimate mixtures, either natural or artificial, of argillaceous with calcareous substances, the calcined product to contain at least 1.7 times as much of lime, by weight, as of the materials which give the lime its hydraulic properties, and to be finely pulverized after said calcination, and thereafter additions or substitutions for the purpose only of regulating certain properties of technical importance to be allowable to not exceeding 2 per cent. of the calcined product."

It will be noted that this definition does not require pulverizing or artificial mixing of the materials prior to burning. It seems probable that the Belgian "natural Portlands" were kept in mind when these requirements were omitted. In dealing with American made cements, however,—and the specifications are headed "Specifications for American Portland Cement,"—it is a serious error to omit these requirements. No true Portland cements are at present manufactured in America from natural mixtures, without pulverizing and artificially mixing the materials prior to burning. Several plants, however, have placed on the market so-called Portland cements made by grinding up together the underburned and overburned materials formed during the burning of natural cements. Several of these brands contain from 5 to 15 per cent. of magnesia; and under no circumstances can they be considered true Portland cements.

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*Professional Paper, No. 28, Corps of Engineers, U.S.A., p. 30.

In view of the conditions above noted, the writer believes that the following definition will be found more satisfactory than the above quoted:

Definition of Portland cement.—Portland cement is an artificial product obtained by finely pulverizing the clinker produced by burning to semi-fusion an intimate mixture of finely ground calcareous and argillaceous material, this mixture consisting approximately of one part of silica and alumina to three parts of carbonate of lime (or an equivalent amount of lime oxide.)

Composition and Constitution.—Portland cement may be said to tend toward a composition approximating to pure tricalcic silicate ($3\,CaO, SiO_2$) which would correspond to the proportion CaO 73.6%, SiO_2 26.4%. As can be seen, however, from the published analyses, actual Portland cements as at present made differ in composition very markedly from this. Alumina is always present in considerable quantity, forming with part of the lime, the dicalcic aluminate ($2\,CaO, SiO_2$). This would give, as stated by Newberry, for the general formula of a pure Portland.

$$X\ (3\,CaO, SiO_2),\ Y\ (2\,CaO, Al_2O_3).$$

But the composition is still further complicated by the presence of accidental impurities, or intentionally added ingredients. These last may be simply adulterants, or they may be added to serve some useful purpose. Calcium sulphate is a type of the latter class. It serves to retard the set of the cement, and, in small quantities, appears to have no injurious effect which would prohibit its use for this purpose. In dome kilns, sufficient sulphur trioxide is generally taken up by the cement from the fuel gases to obviate the necessity for the later addition of calcium sulphate, but in the rotary kiln its addition to the ground cement, in the form of either powdered gypsum or plaster-of-Paris, is a necessity.

Iron oxide, within reasonable limits, seems to act as a substitute for alumina, and the two may be calculated together. Magnesium carbonate is rarely entirely absent from limestones or clays, and magnesia is therefore almost invariably present in the finished cement. Though magnesia, when magnesium carbonate is burned at low temperature, is an active hydraulic material, it does not combine with silica or alumina at the clinkering heat employed in Portland cement manufacture. At the best it is an inert and valueless constituent in the cement; many regard it as positively detrimental in even small amounts, and because of this feeling manufacturers prefer to carry it as low as possible. Newberry has stated that in amounts of less than 3½% it is harmless,—and American Portlands from the Lehigh district usually reach well up toward that limit. In European practice it is carried somewhat lower.

CHAPTER 3.

RAW MATERIALS. GENERAL CONSIDERATIONS.

For the purposes of the present chapter, it will be sufficiently accurate to consider that a Portland cement mixture, when ready for burning, will consist of about 75 per cent. of lime carbonate ($CaCO_3$) and 20 per cent. of silica (SiO_2), alumina (Al_2O_3) and iron oxide (Fe_2O_3) together, the remaining 5 per cent. including any magnesium carbonate, sulphur and alkalies that may be present.

The essential elements which enter into this mixture,—lime, silica, alumina and iron,—are all abundantly and widely distributed in nature, occurring in different forms in many kinds of rocks. It can, therefore, be readily seen that, theoretically, a satisfactory Portland cement mixture could be prepared by combining, in an almost infinite number of ways and proportions, many possible raw materials. Obviously, we, too, might expect to find perfect graduations in the *artificialness* of the mixture, varying from the one extreme where a natural rock of absolutely correct composition was used to the other extreme where two or more materials, in nearly equal amounts, are required to make a mixture of correct composition.

The almost infinite number of raw materials which are theoretically available are, however, reduced to a very few in practice under existing commercial conditions. The necessity for making the mixture as cheaply as possible rules out of consideration a large number of materials which would be considered available if chemical composition was the only thing to be taken into account. Some materials otherwise suitable are too scarce; some are too dificult to pulverize. In consequence, a comparatively few combinations of raw materials are actually used in practice.

In certain localities deposits of argillaceous (clayey) limestone or "cement rock" occur, in which the lime, silica, alumina and iron oxide exist in so nearly the proper proportions that only a relatively small amount (say 10 per cent. or so) of other material is required in order to make a mixture of correct composition.

In the majority of plants, however, most or all of the necessary lime is furnished by one raw material, while the silica, alumina and iron oxide are largely or entirely derived from another raw material. The raw material which furnished the lime is usually natural,—a limestone, chalk or marl; but occasionally an artificial product is used, such as the chemically precipitated lime carbonate which results as waste from alkali manufacture. The silica, alumina and iron oxide of the mixture are usually derived from clays, shales or slates; but in a few plants blast-furnace slag is used as the silico-aluminous ingredient in the manufacture of true Portland cement.

The various combinations of raw material which are at present used in the United States in the manufacture of Portland cement may be grouped under six heads. This grouping is as follows:

1. Argillaceous limestone (cement rock) and pure limestone.
2. Pure hard limestone and clay or shale.
3. Soft chalky limestone and clay.
4. Marl and clay.
5. Alkali waste and clay.
6. Slag and limestone.

ORIGIN AND GENERAL CHARACTERS OF LIMESTONE.

The cement materials which are described in the four following sections as argillaceous limestone or cement rock, pure hard limestone, chalk, and marl, though differing sufficiently in their physical and economic characters to be discussed separately and under different names, agree in that they are all forms of limestone. The origin, chemical composition, physical characters, and properties of limestone will, therefore, be briefly taken up in the present chapter to serve as an introduction to the more detailed statements concerning the various types of limestone to be found in the succeeding chapters.

*Origin of limestones.**—Limestones have been formed largely by the accumulation at the sea bottom of the calcareous remains of such organisms as the foraminifera, corals, and mollusks. Most of the thick and extensive limestone deposits of the United States were probably deep-sea deposits formed in this way. Many of these limestones still show the fossils of which they were formed, but in others all trace of organic origin has been destroyed by the fine grinding to which the shells and corals were subjected before their deposition at the sea-bottom. It is probable also that part of the calcium carbonate of these limestones was a purely chemical deposit from solution, cementing the shell fragments together.

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*For a more detailed discussion of this subject the reader will do well to consult Chapter VIII of Prof. J. F. Kemp's "Handbook of Rocks."

A far less extensive class of limestones—though important in the present connection—owe their origin to the indirect action of organisms. The "marls," so important today as Portland cement materials, fall in this class. As the class is of limited extent, however, its method of origin may be dismissed here, but will be described later in the section on Marls.

Deposition from solution by purely chemical means has unsdoubtedly given rise to numerous limestone deposits. When this deposition took place in caverns or in the open air, it gave rise to onyx deposits and to the "travertine marls" of certain Ohio and other localities; when it took place in isolated portions of the sea through the evaporation of the sea water it gave rise to the limestone beds which so frequently accompany deposits of salt and gypsum.

Varieties of limestone.—A number of terms are in general use for the different varieties of limestone, based upon differences of origin, texture, composition, etc. The more important of these terms will be briefly defined.

The *marbles* are limestones which, through the action of heat and pressure, have become more or less distinctively crystalline. The term *marl*, as at present used in cement manufacture, is applied to a loosely cemented mass of lime carbonate formed in lake basins as described on a later page. *Calcareous tufa* and ***travertine*** are more or less compact limestones deposited by spring or stream waters along their courses. *Oolitic* limestones, so called because of their their resemblance to a mass of fish-roe, are made up of small rounded grains of lime carbonate. ***Chalk*** is a fine-grained limestone composed of finely comminuted shells, particularly those of the foraminifera. The presence of much silica gives rise to a *siliceous* or *cherty* limestone. If the silica present is in combination with alumina, the resulting limestone will be *clayey* or *argillaceous*.

Chemical composition of limestone—A theoretically pure limestone is merely a massive form of the mineral calcite. Such an ideal limestone would therefore consist entirely of calcium carbonate or carbonate of lime, with the formula $CaCO_3$ ($CaO + CO_2$), corresponding to the composition calcium oxide (CaO) 56 per cent.; carbon dioxide or carbonic acid (CO_2) 44 per cent.

As might be expected, the limestones we have to deal with in practice depart more or less widely from this theoretical composition. These departures from ideal purity may take place along either of two lines,—

a. The presence of magnesia in place of part of the lime;

b. The presence of silica, iron, alumina, alkalies, or other impurities.

It seems advisable to discriminate between these two cases, even though a given sample of limestone may fall under both heads, and they will therefore be discussed separately.

a. *The presence of magnesia in place of part of the lime.*—The theoretically pure limestones are, as above noted, composed entirely of calcium carbonate and correspond to the chemical formula $CaCO_3$. Setting aside for the moment the question of the presence or absence of such impurities as iron, alumina, silica, etc., it may be said that lime is rarely the only base in a limestone. During or after the formation of the limestone a certain percentage of magnesia is usually introduced in place of part of the lime, thus giving a more or less magnesian limestone. In the magnesian limestones part of this calcium carbonate is replaced by magnesium carbonate ($MgCO_3$), the general formula for a magnesian limestone being therefore

$$x\,CaCO_3 + y\,MgCO_3.$$

In this formula x may vary from 100% to zero, while y will vary inversely from zero to 100%. In the particular case of this replacement where the two carbonates are united in equal molecular proportions, the resultant rock is called dolomite. It has the formula—$CaCO_3 . MgCO_3$—corresponding to the composition calcium carbonate 54.35 per cent.; magnesium carbonate 45.65 per cent. In the case where the calcium carbonate has been entirely replaced by magnesium carbonate, the resulting pure carbonate of magnesia is called magnesite, having the formula $MgCO_3$ and the composition magnesia (MgO) 47.6 per cent.; carbon dioxide (CO_2), 52.4 per cent.

Rocks of this series may therefore vary in composition from pure calcite-limestones at one end of the series to pure magnesite at the other. The term limestone has, however, been restricted in general use to that part of the series lying in composition between calcite and dolomite, while all those more uncommon phases carrying more magnesium carbonate than the 45.65 per cent. of dolomite are usually described simply as impure magnesites.

The presence of much magnesia in the finished cement is considered undesirable, 3½ per cent. being the maximum permissible under most specifications, and therefore the limestone to be used in Portland cement manufacture should carry not over 5 to 6 per cent. of magnesium carbonate.

Though magnesia is often described as an "impurity" in limestone, this word, as can be seen from the preceding statements, hardly expresses the facts in the case. The magnesium carbonate present, whatever its amount, simply serves to replace an equivalent amount of calcium carbonate, and the resulting rock, whether little or much magnesia is present, is still a pure carbonate rock. With the impurities to be discussed in later paragraphs, however, this is not the case. Silica, alumina, iron, sulphur, alkalies, etc., when present, are actual impurities, not merely chemical replacements of part of the calcium carbonate.

b. *The presence of silica, iron, alumina, alkalies, and other impurities.*—Whether a limestone consists of pure calcium carbonate or more or less of magnesium carbonate, it may also contain a greater or lesser amount of distinct impurities. From the point of view of the cement manufacturer, the more importan of these impurities are silica, alumina, iron, alkalies, and sulphur, all of which have a marked effect on the value of the limestone as a cement material. These impurities will therefore be taken up in the order in which they are named above.

The silica in a limestone may occur either in combination with alumina, as a clayey impurity, or not combined with alumina. As the effect on the value of the limestone would be very different in the two cases, they will be taken up separately.

Silica alone.—Silica, when present in a limestone containing no alumina, may occur in one of three forms, and the form in which it occurs is of great importance in connection with cement manufacture.

(1) In perhaps its commonest form, silica is present in nodules, masses or beds of flint or chert. Silica occurring in this form will not readily enter into combination with the lime of a cement mixture, and a cherty or flinty limestone is therefore almost useless in cement manufacture.

(2) In a few cases, as in the hydraulic limestone of Teil, France, a large amount of silica is present and very little alumina; notwithstanding which the silica readily combines with the lime on burning. It is probable that in such cases the silica is present in the limestone in a very finely divided condition, or possibly as hydrated silica, possibly as the result of chemical precipitation or of organic action. In the majority of cases, however, a highly siliceous limestone will not make a cement on burning unless it contains alumina in addition to the silica.

(3) In the crystalline limestone (marbles) and less commonly in uncrystalline limestones, whatever silica is present may occur as a complex silicate in the form of shreds of mica, hornblende, or other silicate mineral. In this form silicate is somewhat intractable in the kiln, and mica and other silicate minerals are therefore to be regarded as inert and useless impurities in a cement rock. These silicates will flux at a lower temperature than pure silica and are thus not so troublesome as flint or chert. They are, however, much less serviceable than, if the same amount of silica were present in combination with alumina as a clay.

Silica with alumina.—Silica and alumina, combined in the form of clay, are common impurities in limestone, and are of special interest to the cement manufacturer. The best known example of such an argillaceous limestone is the cement rock of the Lehigh district of Pennsylvania. Silica and alumina, when present in this combined form, combine readily with the lime under the action of heat, and an argillaceous limestone therefore forms an excellent basis for a Portland cement mixture.

Iron.—Iron when present in a limestone occurs commonly as the oxide (Fe_2O_3), or sulphide (FeS_2); more rarely as iron carbonate or in a complex silicate. Iron in the oxide, carbonate or silicate form, is a useful flux, aiding in the combination of the lime and silica in the kiln. When present as a sulphide, in the form of the mineral pyrite it is to be avoided in quantities over 2 or 3 per cent.

Physical characters of limestones.—In texture, hardness, and compactness, the limestones vary from the loosely consolidated marls through the chalks to the hard compact limestones and marbles. Parallel with these variations are variations in absorptive properties and density. The chalky limestones may run as low in specific gravity as 1.85, corresponding to a weight of say 110 pounds per cubif oot, while the compact limestones commonly used for building purposes range in specific gravity between 2.3 and 2.9, corresponding approximately to a range in weight of from 140 to 185 pounds per cubic foot.

From the point of view of the Portland cement manufacturer, these variations in physical properties are of economic interest chiefly in their bearing upon two points: the percentage of water carried by the limestone as quarried, and the ease with which the rock may be crushed and pulverized. To some extent the two properties counterbalance each other; the softer the limestone the more absorbent is it likely to be. These purely economic features will be discussed in more detail in later chapters.

Effect of heating on limestone.—On heating a non-magnesian limestone to or above 300° C., its carbon dioxide will be driven off, leaving quicklime (calcium oxide, CaO). If a magnesian limestone be similarly treated, the product would be a mixture of calcium oxide and magnesium oxide (MgO). The rapidity and perfection of this decomposition can be increased by passing steam or air through the burning mass. In practice this is accomplished either by the direct injection of air or steam, or more simply by thoroughly wetting the limestone before putting it into the kiln.

If, however, the limestone contains an appreciable amount of silica, alumina and iron, the effects of heat will not be of so simple a character. At temperature of 800° C. and upwards these clayey impurities will combine with the lime oxide, giving silicates, aluminates and related salts of lime. In this manner a natural cement will be produced. An artificial mixture of certain and uniform composition, burned at a higher temperature, will give a Portland cement, the details of whose manufacture are discussed on later pages.

CHAPTER 4.

RAW MATERIALS IN DETAIL.

Argillaceous Limestone: Cement Rock.

An argillaceous limestone containing approximately 75 per cent. of lime carbonate and 20 per cent. of clayey materials (silica, alumina, and iron oxide), would, of course, be the ideal material for use in the manufacture of Portland cement, as such rock would contain within itself in the proper proportions all the ingredients necessary for the manufacture of a good Portland. It would require the addition of no other material, but when burnt alone would give a good cement. This ideal cement material is, of course, never realized in practice, but certain deposits of argillaceous limestone approach the ideal composition very closely.

The most important of these argillaceous limestone or "cement rock" deposits is, at present, that which is so extensively utilized in Portland cement manufacture in the "Lehigh district" of Pennsylvania and New Jersey. As this area still furnishes about two-thirds of all the Portland cement manufactured in the United States, its raw materials will be described in some detail

Cement rock of the Lehigh district.—The Lehigh district of the cement trade comprises parts of Berks, Lehigh, and Northampton counties, Pennsylvania, and of Warren county, New Jersey. Within this relatively small area about twenty Portland cement mills are located, producing slightly over two-thirds of the entire American output. As deposits of the cement rock used by these plants extend far beyond the present "Lehigh district," a marked extension of the district will probably take place as the needs for larger supplies of raw material becomes more apparent.

The "cement rock" of the Lehigh district is a highly argillaceous limestone of Trenton (Lower Silurian) age. The formation is about 300 feet in thickness in this area. The rock is a very dark gray in color and usually has a slaty fracture. In composition it ranges from about 60 per cent. lime carbonate with 30 per cent. of clayey material, up to say 80 per cent. lime carbonate with 15 per cent. of silica, alumina and iron. The lower beds of the formation are always higher in lime carbonate than are the beds nearer the top of the formation. The content of magnesium carbonate in these cement rocks is always high, (as Portland cement materials go), ranging from 3 to 6 per cent.

Near, and in some cases immediately underlying these cement beds, are beds of purer limestone ranging from 85 to 96 per cent. lime carbonate. The usual practice in the Pennsylvania and New Jersey plants has been therefore to mix a relatively small amount of this purer limestone with the low lime "cement rock" in such proportions as to give a cement mixture of proper composition.

The economic and technologic advantages of using such a combination of materials are very evident. Both the pure limestone and the cement rock, particularly the latter, can be quarried very easily and cheaply. As quarried they carry but little water so that the expense of dryidg them is slight. The fact that about four-fifths of the cement mixture will be made up of a natural cement rock permits coarser granding of the raw mixture than would be permissible in plants using pure limestone or marl with clay. This point is more fully explained on a later page. It seems probable, also, that when using a natural cement rock as part of the mixture the amount of fuel necessary to clinker the mixture is less than when pure limestone is mixed with clay.

Such mixtures of argillaceous limestone or "cement rock" with a small amount of pure limestone evidently possess important advantages over mixtures of pure hard limestone or marl with clay. They are, on the other hand, less advantageous as cement materials than the chalky limestones discussed on later pages.

The analyses in Table 2 are fairly representative of the materials employed in the Lehigh district. The first four analyses are of "cement rock"; the last two are of the purer limestone used for mixing with it.

Analyses of Lehigh district cement materials.

	Cement rock				Limestone	
Silica (SiO2)	10.02	9.52	14.52	16.10	3.02	1.98
Alumina (Al2O3) Iron Oxide (Fe2O3)	6.26	4.72	6.52	2.20	1.90	0.70
Lime carbonate (CaCO3)	78.65	80.71	73.52	76.23	92.05	95.15
Magnesium carbonate (MgCO3)	4.71	4.92	4.69	3.54	3.04	2.03

"*Cement rock" in other parts of the United States.*—Certain Portland cement plants, particularly in the western United States, are using combinations of materials closely similar to those in the Lehigh district. Analyses of the materials used at several of these plants are given in Table III.

Analyses of "cement rock" materials from the western United States.

	Utah.		California		Colorado	
	Cement rock	Limestone	Cement rock	Limestone	Cement rock	Limestone
Silica (SiO2)	21.2	6.8	20.06	7.12	14.20	
Alumina (Al2O3)	8.0	3.0	10.07	2.36	5.21	
Iron Oxide (Fe2O3)			3.39	1.16	1.73	
Lime carbonate (CaCO3)	62.08	89.8	63.40	87.70	75.10	88.0
Magnesium carbonate (MgCO3)	3.8	0.76	1.51	0.84	1.10	

In addition to the "cement rocks" noted in this chapter, it is necessary to call attention to the fact that many of the chalky limestones discussed on page 20 are sufficiently argillaceous to be classed as 'cement rocks.'' Because of their softness, however, all the chalky limestones will be described together.

Pure hard limestones.

Soon after the American Portland cement industry had become fairly well established in the Lehigh district, attempts were made in New York State to manufacture Portland cement from a mixture of pure limestone and clay. These attempts were not commercially successful, and although their lack of success was not due to any defects in the limestone used, a certain prejudice arose against the use of the hard limestones. In recent years, however, this has disappeared, and a very large proportion of the American output is now made from mixtures of limestone with clay or shale. (See page 21 for comparative figures.) This reëstablishment in favor of the hard limestones is doubtless due, in great part, to recent improvements in grinding machinery, for the purer limestones are usually much harder than argillaceous limestones like the Lehigh district "cement rock," and it was very difficult to pulverize them finely and cheaply with the crushing appliances in use when the Portland cement industry was first started in America.

A series of analyses of representative pure hard limestones, together with analyses of the clays or shales with which they are mixed, is given in the table.

Analyses of pure hard limestones and clayey materials.

	Limestones.			
Silica (SiO2)	1.72	0.86	0.56	0.40
Alumina (Al2O2)	1.63	0.63	1.23	0.44
Iron oxide (Fe2O3)	6.59	1.03	0.29	
Lime carbonate (CaCO3)	90.58	97.06	97.23	97.99
Magnesium carbonate (MgCO3)	....	....	0.75	0.42

	Clays and Shales.			
Silica (SiO2)	63.56	55.80	56.30	60.00
Alumina (Al2O2)				23.36
Iron oxide (Fe2O3)	27.32	30.20	29.86	4.32
Lime carbonate (CaCO3)	3.60	2.54	....	1.70
Magnesium carbonate (MgCO3)	2.60	....	....	1.50

The first limestone analysis given in the above table represents a curious type, used in several plants in the Middle West. As will be noted, it is a relatively impure limestone, but its principal impurity is iron oxide. It contains 8.22 per cent. of iron oxide and alumina, as compared with 1.72 per cent. of silica; and therefore demands great care in the selection of a suitable high-silica clay to mix with it.

Soft Limestones: Chalk.

Origin and general character.—Chalk, properly speaking, is a pure carbonate of lime composed of the remains of the shells of minute organisms, among which those of foraminifere are especially prominent. The chalks and soft limestones discussed in this chapter agree, not only in having usually originated in this way, but also in being rather soft and therefore readily and cheaply crushed and pulverized. As Portland cement materials they are, therefore, almost ideal. One defect, however, which to a small extent counterbalances their obvious advantages is the fact that most of these soft, chalky limestones absorb water quite readily. A chalky limestone which in a dry season will not carry over 2 per cent. of moisture as quarried, may, in consequence of prolonged wet weather show as high as 15 or 20 per cent. of water. This difficulty can, of course, be avoided if care be taken in quarrying to avoid unnecessary exposure to water and, if necessary, to provide facilities for storing a supply of the raw materials during wet seasons.

Geographic and geologic distribution in the United States.—The chalks and chalky limestones are confined almost entirely to certain southern and western States. They are all of approximately the same geologic ages,—Cretaceous or Tertiary,—and are mostly confined to one division of the Cretaceous. The principal chalk or soft limestone deposits available for use in Portland cement manufacture occur in three widely separated areas, occupying respectively (*a*) parts of Alabama and Mississippi; (*b*) parts of Texas and Arkansas; and, (*c*) parts of Iowa, Nebraska, North and South Dakota.

Composition.—In composition these chalks, or "rotten limestones," vary from a rather pure calcium carbonate, low in both magnesia and clayey materials, to an impure clayey limestone, requiring little additional clay to make it fit for use in Portland cement manufacture. Analyses quoted from various authors of a number of these chalky limestones are given in Table IV, and will serve to show their range of composition.

Analyses of Chalky Limestones.

	Demopolis, Ala.	San Antonio, Texas.	Dallas, Texas.	White Cliffs, Ark.	Yankton, S. Dak.	Milton, N. Dak.
Silica	12.13	5.77	23.55	7.97	8.20	9.15
Alumina	4.17	2.12				4.80
Iron oxide	3.28		1.50	1.09	7.07	2.30
Lime carbonate	75.07	90.15	70.21	88.64	83.59	63.75
Magnesium carb'te	.92	.15	.58	.73	n.d.	1.25

Fresh-Water Marls.

Marls, in the sense in which the term is used in the Portland cement industry, are incoherent limestones which have been deposited in the basins of existing or extinct lakes. So far as chemical composition is concerned, marls are practically pure limestones, being composed entirely of calcium carbonate. Physically, however, they differ greatly from the compact rocks which are commonly described as limestones, for the marls are granular, incoherent deposits. This curious physical character of marls is due to the conditions under which they have been deposited, and varies somewhat according to the particular conditions which governed their deposition in different localities.

A warning to the reader concerning other uses of the term "marl" may profitably be introduced here. The meaning above given is that in which the term marl is commonly used in the cement industry at the present day. But in geological and agricultural reports, particularly in those issued before the Portland cement industry became prominent in this country, the term marl has been used to cover several very different substances. The following three uses of the term will be found particularly common, and must be guarded against when such reports are being examined in search for descriptions of deposits of cement materials.

(1.) In early days the term "marls" and "marlytes" were used to describe deposits of calcareous shales—and often covered shales which were not particularly calcareous. This use of the term will be found in many of the earlier geological reports issued by New York, Ohio, and other interior States.

(2.) In New Jersey and the States southward bordering on the Atlantic and Gulf of Mexico, the term marl is commonly applied to deposits of soft chalky or unconsolidated limestone, often containing considerable clayey and phosphatic matter. These limestones are of marine origin, and not related to the fresh-water marl deposits which are the subject of the present chapter.

(3.) In the same States as are included in the last paragraph, but particularly in New Jersey and Virginia, large deposits of the so-called 'green sand marls" occur. This material is, in no way, related to the true marls (which are essentially lime carbonates), but consists almost entirely of an iron silicate, with very small percentages of clayey, calcareous, and phosphatic matter.

Origin or marls.—The exact cause of the deposition of marls has been the subject of much investigation and discussion, particularly in the past few years, since they have become of economic importance. The reader who wishes to obtain further details concerning this question will do well to refer to the following series of papers.

(1.) Blatchley, W. S., and Ashley, G. H. The Lakes of Northern Indiana, and their associated marl deposits, in 25th Ann. Rept. Indiana Dept. Geology and Natural Resources, pp. 31-321.

(2.) Davis, C. A. A contribution to the natural history of marl. Journal of Geology, Vol. 8, pp. 485-497.

(3.) Davis, C. A. Second contribution to the natural history of marl. Journal of Geology, Vol. 9, pp. 491-506.

(4.) Davis, C. A. A contribution to the natural history of marl. Vol. 8, pt. 3, Reports Michigan Geological Survey, pp. 65-102.

(5.) Lane, A. C. Notes on the origin of Michigan bog limes. Vol. 8, pt. 3, Reports Michigan Geological Survey, pp. 199-223.

Disregarding the points in controversy, which are of no particular practical importance, it may be said that marls are deposited in lakes by spring or stream waters carrying lime carbonate in solution. The actual deposition is in part due to purely physical and chemical causes, and in part to the direct or indirect action of animal or vegetable life. The result, in any case, is that a calcareous deposit forms along the sides and over the bottom of the lake, this deposit consisting of lime carbonate, mostly in a finely granular form, interspersed with shells and shell fragments.

Geographic distribution of marl deposits.—The geographic distribution of marl deposits is intimately related to the geologic history of the region in which they occur. Marl beds are, as indicated in the preceding section, the result of the filling of lake basins. Lakes are not common except in those portions of the United States which were affected by glacial action, since lakes are in general due to the damming of streams by glacial material. Workable marl deposits, therefore, are almost exclusively confined to those portions of the United States and Canada lying north of the former southern limit of the glaciers.

Marl beds are found in the New England States, where they are seldom of important size, and in New York, where large beds occur in the central and western portions of the State. Deposits are frequent and important in Michigan, and in the northern portions of Ohio, Indiana, and Illinois. Marl beds occur in Wisconsin and Minnesota, but have not been as yet exploited for cement manufacture.

Composition.—As shown by the analyses below, marls are usually very pure lime carbonates. They, therefore, require the addition of considerable clay to bring them up to the proper composition for a Portland cement mixture.

The marls are readily excavated, but necessarily carry a large percentage of water. The mixture, on this account, is commonly made in the wet way, which necessitates driving off a high percentage of water in the kilns. Analyses of typical marls and clays are given in the following table.

Analyses of marls and clays used in cement plants.

	Marl.			Clay.		
Silica	0.25	3.0	1.60	40.48	52.0	63.75
Alumina					17.0	16.40
Iron oxide	.10		1.55	20.95	5.0	6.35
Lime carbonate	94.39	93.0	88.9	25.80	20.0	4.0
Magnesium carb'te	.38	1.5	.94	.99	....	2.1

Alkali Waste.

A very large amount of waste material results from the process used at alkali works in the manufacture of caustic soda. This waste material is largely a precipitated form of calcium carbonate, and if it is sufficiently free from impurities, it furnishes a cheap source of lime for use in Portland cement manufacture.

The availability of alkali waste for this purpose depends largely on what process was used at the alkali plant. Leblanc process waste, for example, carries a very large percentage of sulphides, which prevents its use as a Portland cement material. Waste resulting from the use of the ammonia process, on the other hand, is usually a very pure mass of lime, mostly in the form of carbonate, though a little lime hydrate is commonly also present. As pyrite is not used in the ammonia process, its waste is usually low enough in sulphur to be used as a cement material. The waste may carry a low or a very high percentage of magnesia, according to the character of the limestone that has been used. When a low-magnesia limestone has been used, the resulting waste is a very satisfactory Portland cement material.

The following analyses are fairly representative of the waste obtained at alkali plants using the ammonia process.

Analyses of alkali waste.

	1	2	3	4
Silica (SiO_2)	0.60	1.75	1.98	0.98
Alumina (Al_2O_3)	3.04	0.61	1.41	1.62
Iron oxide (Fe_2O_3)			1.38	
Lime (CaO)	53.33	50.60	48.29	50.44
Magnesia (MgO)	0.48	5.35	1.51	4.97
Alkalies (Na_2O, K_2O)	0.20	0.64	0.64	0.50
Sulphur trioxide (Co_3)	n.d.	n.d.	1.26	n.d.
Sulphur (S)	n.d.	0.10	n.d.	0.06
Carbon dioxide (CO_2)	42.43	41.70	39.60	n.d.
Water and organic matter	n.d.		3.80	n.d.

Of the analyses quoted in the preceding table, those in the first and third columns represent materials which are actually used in Portland cement manufacture in England and the United States. The alkali wastes whose analyses are given in the second and fourth columns are notably too high in magnesia to be advisable for such use.

Blast furnace slag.

True Portland cements, which must be sharply distinguished from the slag (or puzzolan) cements can be made from mixtures which contain blast furnace slag as one ingredient. In this case the slag is intimately mixed with limestone and the mixture is finely powdered. It is then burned in kilns and the resulting clinker pulverized.

The slags from iron furnaces consist essentially of lime (CaO), silica (SiO_2), and alumina (Al_2O_3); though small percentages of iron oxide (FeO), magnesia (MgO), and sulphur (S), are commonly present. Slag may therefore be regarded as a very impure limestone or a very calcareous clay.

The slag used at a German Portland cement plant has the following range in composition.

Analysis of slag used in Portland cement manufacture.

Silicia (SiO2)	30.	35.
Alumina (Al2O3)	10.	14.
Iron oxide (FeO)	0.2	1.2
Lime (CaO)	46.	49.
Magnesia (MgO)	0.5	3.5
Sulphur trioxide (SO3)	0.2	0.6

Clays and Shales.

Clays are ultimately derived from the decay of older rocks, the finer particles resulting from this decay being carried off and deposited by streams along their channels, in lakes, or along parts of the sea coast or sea bottom as beds of clay. In chemical composition the clays are composed essentially of silica and alumina, though iron oxide is almost invariably present in more or less amount, while lime, magnesia, alkalies and sulphur are of frequent occurrence, though usually only in small percentages.

Shales are clays which have become hardened by pressure. The so-called "fire-clays" of the Coal Measures are shales, as are many of the other "clays" of commerce.

For use as Portland cement materials clays or shales should be as free as possible from gravel and sand, as the silica present as pebbles or grit is practically inert in the kiln unless ground more finely than is economically practicable. In composition they should not carry less than 55 per cent. of silica, and preferably from 60 to 70 per cent. The alumina and iron oxide together should not amount to more than one-half the percentage of silica, and the composition will usually be better the nearer the ratio $Al_2O_3 + Fe_2O_3 = \frac{SiO_2}{3}$ is approached.

Nodules of lime carbonate, gypsum or pyrite, if present in any quantity, are undesirable; though the lime carbonate is not absolutely injurious. Magnesia and alkalis should be low, preferably not above 3 per cent.

Analyses of clays and shales used in various American Portland cement plants will be found on pages 27 and 30.

Slate.

Slate is, so far as origin is concerned, merely a form of shale in which a fine, even and parallel cleavage has been developed by pressure. In composition, therefore, it will vary exactly as do the shales considered on previous pages, and so far as composition alone is concerned, slate would not be worthy of more attention, as a Portland cement material, than any other shale.

Commercial considerations in connection with the slate industry, however, make slate a very important possible source of cement material. Good roofing slate is a relatively scarce material, and commands a good price when found. In the preparation of roofing slate for the market so much material is lost during sawing, splitting, etc., that only about 10 to 25 per cent. of the amount quarried is salable as slate. The remaining 75 to 90 per cent. is of no service to the slate miner. It is sent to the dump heap, and is a continual source of trouble and expense. This very material, however, as can be seen from the analyses quoted below, is often admirable for use, in connection with limestone, in a Portland cement mixture. As it is a waste product, it could be obtained very cheaply by the cement manufacturer.

Composition of American roofing slates.

	Max.	Average	Min.
Silica (SiO_2)	68.62	60.64	54.05
Alumina (Al_2O_3)	24.71	18.05	9.77
Iron oxides (FeO, Fe_2O_3)	10.66	6.87	2.18
Lime (CaO)	5.23	1.54	....
Magnesia (MgO)	6.43	2.60	0.12
Alkalies (K_2O, Na_2O)	8.68	4.74	1.93
Ferrous sulphide (FeS_2)	....	0.38	....
Carbon dioxide (CO_2)	....	1.47	....
Water of combination	....	3.51	....
Moisture, below 110°C	....	0.62	....

CHAPTER 5.

ECONOMIC CONSIDERATIONS AND METHODS OF MANUFACTURE.

Determining the possible value for Portland cement manufacture of a deposit of raw material is a complex problem, depending upon a number of distinct factors, all of which must be given due consideration. The more important of these factors are:

(1.) Chemical composition of the material.
(2.) Physical character of the material.
(3.) Amount of material available.
(4.) Location of the deposit with respect to transportation routes.
(5.) Location of the deposit with respect to fuel supplies.
(6.) Location of the deposit with respect to markets.

The natural raw materials used at present in Portland cement manufacture are obtained by one of three methods,—(a) quarrying; (b) mining, and (c) dredging. When the cement manufacturer is given an opportunity to choose between these different methods of excavation, his choice will depend partly on the physical character of the material to be excavated and partly on the topographical and geological conditions. Usually, however, there is no opportunity for a choice of methods, for in any given case one of the methods will be so evidently the only possible mode of handling the material as to leave no room for other considerations.

The three different methods of excavation will first be briefly considered, after which the cost of raw materials at the mill will be discussed.

Quarrying.—In the following pages the term "quarrying" will be used to cover all methods of obtaining raw materials from open excavations,—quarries, cuts or pits—whether the material excavated be a limestone, a shale or a clay. Quarrying is the most natural and common method of excavating the raw materials for cement manufacture. If marl, which is usually worked by dredging, be excluded from consideration, it is probably within safe limits to say that 95 per cent. of the raw materials used at American Portland cement plants are obtained by quarrying. If marls be included, the percentages excavated by different methods would probably be about as follows: Quarrying, 88 per cent.; dredging, 10 per cent.; mining, 2 per cent.

In the majority of limestone quarries the material is blasted out and loaded by hand on to cars or carts. In a few limestone quarries a steam shovel is employed to do the loading, and in shale quarries this use of steam shovels is more frequent. In certain clay and shale pits, where the materials are of suitable character, the steam shovel does all the work, both excavating and loading the raw materials.

The rock is usually shipped to the mill as quarried without any treatment except sledging it to convenient size for loading. At a few quarries, however, a crushing plant is installed at the quarry, and the rock is sent as crushed stone to the mill. A few plants also have installed their driers at the quarry, and dry the stone before shipping it to the mill. Except the saving of mill space thus attained, this practice seems to have little to commend it.

Mining.—The term "mining" will be used, in distinction from "quarrying," to cover methods of obtaining any kind of raw material by underground workings, through shafts or tunnels. Mining is, of course, rarely employed in excavating materials of such low value per ton as the raw materials for Portland cement manufacture. Occasionally, however, when a thin bed of limestone or shale is being worked, its dip will carry it under such a thickness of other strata as to make mining cheaper than stripping and quarrying, for that particular case.

Mining is considerably more expensive work than quarrying, but there are a few advantages about it that serve to counterbalance the greater cost per ton of raw material. A mine can be worked steadily and economically in all kinds of weather, while an open cut or quarry is commonly in a more or less unworkable condition for about three months of the year. Material won by mining is, moreover, always dry and clean.

Dredging.—The term "dredging" will be here used to cover all methods of excavating soft, wet, raw materials. The fact that the materials are wet implies that the deposit occurs in a basin or depression; and this in turn implies that the mill is probably located at a higher elevation than the deposit of raw material, thus necessitating up-hill transportation to the mill.

The only raw material for Portland cement manufacture that is extensively worked by dredging, in the United States, is marl. Occasionally the clay used is obtained from deposits overlain by more or less water; but this is rarely done except where the marl and clay are interbedded or associated in the same deposit.

A marl deposit, in addition to containing much water diffused throughout its mass, is usually covered by a more or less considerable depth of water. This will frequently require the partial draining of the basin in order to get tracks laid near enough to be of service.

In dredging marl the excavator is frequently mounted on a barge, which floats in a channel resulting from previous investigation. Occasionally, in deposits which either were originally covered by very little water or have been drained, the shovel is mounted on a car, running on tracks laid along the edge of the deposit.

The material brought up by the dredge may be transported to the mill in two different ways, the choice depending largely upon the manufacturing processes in use at the plant. At plants using dome or chamber kilns, or where the marl is to be dried before sending to the kiln, the excavated marl is usually loaded by the shovel on cars, and hauled to the mill by horse or steam power. At normal marl plants, using a very wet mixture, it is probable that the second method of transportation is more economical. This consists of dumping the marl from the excavator into tanks, adding sufficient water to make it flow readily, and pumping the fluid mixture to the mill in pipes.

Cost of raw materials at mill.—The most natural way, perhaps, to express the cost of the raw material delivered at the mill would be to state it as being so many cents uper ton or cubic yard of raw material; and this is the method followed by quarrymen or miners in general. To the cement manufacturer, however, such an estimate is not so suitable as one based on the cost of raw materials per ton or barrel of finished cement.

In the case of hard and comparatively dry limestones or shales, it may be considered that the raw material loses 33 1-3 per cent.

in weight on burning. Converting this relation into pounds of raw material and of clinker we find that 600 pounds of dry raw material will make about 400 pounds of clinker. Allowing something for other losses in the process of manufacture, it is convenient and sufficiently accurate to estimate that 600 pounds of dry raw material will give one barrel of finished cement. These estimates must be increased if the raw material carry any appreciable amount of water. Clays will frequently contain 15 per cent. or more of water; while soft chalky limestones, if quarried during wet weather, may carry as high as 15 to over 20 per cent. A Portland cement mixture composed of a pure chalky limestone and a clay might, therefore, average 10 to 20 per cent. of water; and consequently about 700 pounds of such a mixture would be required to make one barrel of finished cement.

With marls the loss on drying and burning is much greater. Russell states* that according to determinations made by E. D. natural deposits, contains about 47 1-2 pounds of lime carbonate and 48 pounds of water. In making cement from a mixture of marl and clay, therefore, it would be necessary to figure on excavating and transporting over 1,000 pounds of raw material for every barrel of finished cement.

From the preceding notes it will be understood that the cost of raw materials at the mill, per barrel of cement, will vary not only with the cost of excavation, but with the kind of materials in use.

In dealing with hard dry materials, extracted from open quarries near the mills, the cost of raw materials may vary between 8 cents and 15 cents per barrel of cement. The lower figure named is probably about the lowest attainable with good management and under favorable natural conditions; the higher figure is probably a maximum for fairly careful management of a quarry under eastern labor conditions. When it is necessary to mine the materials, the cost will be somewhat increased. Cement rock has been mined at a cost equivalent to 10 cents per barrel of cement; but the figure is attained under particularly favorable conditions. The cost of mining and transportation may reach from this figure up to 20 cents per barrel.

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*22nd Ann. Rept., U. S. Geol. Surv., pt. 3, p. 657.

METHODS OF MANUFACTURE.

If, as in the present volume, we exclude from consideration the so-called "natural Portlands," Portland cement may be regarded as being an artificial product, obtained by burning to semi-fusion an intimate mixture of pulverized materials, this mixture containing lime, silica and alumina, varying in proportion only with certain narrow limits; and by crushing finely the clinker resulting from this burning.

If this restricted definition of Portland cement be accepted, four points may be regarded as being of cardinal importance in its manufacture. These are:

(1) The cement mixture must be of the proper chemical composition.

(2) The materials of which it is composed must be carefully ground and intimately mixed before burning.

(3) The mixture must be burned at the proper temperature.

(4) After burning, the resulting clinker must be finely ground.

The first named of these points—the chemical composition of the mixture—can be more advantageously discussed after the other three points have been disposed of. The subjects will, therefore, be taken up in the following order:

Preparation of the mixture for the kiln.
Burning the mixture.
Grinding the clinker, addition of gypsum, etc.
Composition and properties of Portland cement.

PREPARATION OF THE MIXTURE FOR THE KILN.

The preparation of the mixture for the kiln involves the reduction of both of the raw materials to a very fine powder, and their intimate mixture. In practice the raw materials are usually crushed more or less finely, and then mixed, after which the final reduction to powder takes place. Two general methods of treatment—the dry and the wet—are in use at different plants. Unless the limey constituent of the mixture is a marl, already full of water, the dry method is almost invariably followed. This consists merely in keeping the materials in as dry a condition as possible throughout the entire process of crushing and mixing; and, if the raw materials originally contained a little moisture, they are dried before being powdered and mixed. In the wet method, on the other hand, the materials are powdered and mixed while in a very fluid state, containing 60 per cent. or more of water.

DRYING THE RAW MATERIALS.—With the exception of the marls and clays used in the wet method of manufacture, Portland cement materials are usually dried before the grinding is commenced. This is necessary because the raw materials, as they come from the quarry, pit or mine, will almost invariably carry appreciable, though often very small, percentages of water, which greatly reduces the efficiency of most modern types of grinding mills, and tends to clog the discharge screens.

PERCENTAGE OF WATER IN RAW MATERIALS.—The percentage of water thus carried by the crude raw material will depend largely on the character of the material; partly on the method of handling and storing it; and partly on weather conditions.

In the case of hard limestones, freshly quarried, the water will commonly range from 1-2 per cent. to 3 per cent., rarely reaching or exceeding the higher figure except in the very wet quarries or during a rainy season. Such limestones, comparatively dry when quarried, are frequently sent to the grinding mills without artificial drying.

With the soft, chalky limestones, which absorb water very rapidly, the percentage can usually be kept down to 5 per cent. or less in dry weather; while prolonged wet weather may necessitate the handling at the mill of material carrying as high as 15 to 20 per cent. of water.

The clays present a much more complicated case. In addition to the hydroscopic or mechanically-held water that they may contain, there is also always present a certain percentage of chemically combined water. The amount of hydroscopic water present will depnd on the treatment and exposure of the clay; and may vary from 1 per cent. or so in clays which have been stored and air-dried to as high as 30 per cent. in fresh clays. The chemically combined water will depend largely on the composition of the clay, and may vary from 5 to 12 per cent. The hygroscopic or mechanically held water of clays can be driven off at a temperature of 212° F., while the chemically combined water is lost only at a low red heat. The total water, therefore, to be driven off from clays may range from 6 to 42 per cent., depending on the weather, the drainage of the clay pit, and the care taken in preventing unnecessary exposure to moisture of the excavated clay. The average total amount of moisture will probably be about 15 per cent.

In dealing with shales, the mechanically-held water will rarely rise above 10 per cent., and can commonly be kept well below that limit. An additional 2 to 7 per cent. of water will be carried, by any shale, in a state of chemical combination.

At a few plants marl is used, with clay, in a dry process. As noted elsewhere, the marls, as excavated, carry usually about 50 per cent. of water. This case presents a more difficult problem than do the other raw materials, because the vegetable matter usually present in marls is extremely retentive of water.

It will be seen, therefore, that cement materials may carry from 1 per cent. to 50 per cent. of water when they reach the mill. In a dry process it is necessary to remove practically all of this water before commencing the grinding of the materials. One reason for this is that fine pulverizing can not be economically or satisfactorily accomplished unless absolutely dry material is fed to the grinding machinery.

Another reason, which is one of convenience rather than of necessity, is that the presence of water in the raw materials complicates the calculation of the cement mixture.

Methods and cost of drying.—The type of dryer commonly used in cement plants is a cylinder approximately 5 feet in diameter and 40 feet or so in length, set at a slight inclination to the horizontal, and rotating on bearings. The wet raw material is fed in at the upper end of the cylinder, and it moves gradually toward the lower end, under the influence of gravity, as the cylinder revolves. In many dryers angle irons are bolted to the interior in such a way as to lift and drop the raw material alternately, thus exposing it more completely to the action of the heated gases, and materially assisting in the drying process. The dried raw material falls from the lower end of the cylinder into an elevator boot, and is then carried to the grinding mills.

The drying cylinder is heated either by a separate furnace or by waste gases from the cement kiln. In either case the products of combustion are introduced into the cylinder at its lower end, and drawn through it, and escape up a stack set at the upper end of the dryer.

The dryer above described is the simplest, and is most commonly used. For handling the small percentages of water contained in most cement materials it is very efficient, but for dealing with high percentages of water, such as are encountered when marl is to be used in a dry process, it seems probable that double-heating dryers will be found more economical. This type is exemplified by the Ruggles-Coles dryer, in which a double cylinder is employed. The wet raw material is fed into the space between the inner and outer cylinders, while the heated gases pass first through the inner cylinder, and then, in a reverse direction, through the space between the inner and outer cylinders. This double-heating type of dryer is employed in almost all of the slag cement plants in the United States, and is also in use in several Portland cement plants.

When vertical kilns were in use, drying floors and drying tunnels were extensively used, but at present they can be found in only a few places, being everywhere else supplanted by the rotary dryers.

The cost of drying will depend on the cost of fuel, the percentage of water in the wet material and the type of dryer. Even under the most unfavorable conditions five pounds of water can be expected to be evaporated per pound of coal used, while a good dryer will usually evaporate seven or eight pounds of water per pound of coal.

GRINDING AND MIXING—DRY METHODS.—Part at least of the grinding is usually accomplished before the drying, but for convenience the subjects have been separated in the present paper. Usually the limestone is sent through a crusher at the quarry or mill before being dried, and occasionally the raw material is further reduced in a Williams mill, etc., before drying, but the principal part of the reduction always takes place after the material has been dried.

After the two raw materials have been separately dried they may be mixed immediately, or each may be further reduced separately before mixing. Automatic mixers, of which many types are on the market, give a mixture in proportions determined upon from analysis of the materials.

The further reduction of the mixture is usually carried on in two stages, the material being ground to say 30 mesh in a ball mill, komminuter, Griffin mill, etc., and finally reduced in a tube mill. At a few plants, however, single stage reduction is practiced in Griffn or Huntington mills, while at the Edison plant at Stewartsville, N. J., the reduction is accomplished in a series of rolls.

The majority of plants use either the Griffin mill and tube mill or the ball and tube mills, and there is probably little difference in the cost of operating these two combinations. The ball mill has never been quite as much of a success as its companion, the tube mill, and has been replaced at several plants by the komminuter.

Fineness of Mixture.—After its final reduction, and when ready for burning, the mixture will usually run from 90 to 95 per cent. through a 100-mesh sieve. In the plants of the Lehigh district the mixture is rarely crushed as fine as when limestone and clay are used. Newberry* has pointed out in explanation for this that an argillaceous limestone (cement rock) mixed with a comparatively small quantity of purer limestone, as in the Lehigh plants, requires less thorough mixing and less fine grinding than when a mixture of limestone and clay (or marl and clay) is uesd, for even the coarser particles of the argillaceous limestone will vary so little in chemical composition from the proper mixture as to affect the quality of the resulting cement but little, should either mixing or grinding be incompletely accomplished.

A very good example of typical Lehigh Valley grinding of raw material is afforded by a specimen examined* by Prof. E. D. Campbell. This specimen of raw mix ready for burning was furnished by one of the best of the eastern Pennsylvania cement plants. A mechanical analysis of it showed the following results:

	Mesh of sieve.		
	50	100	200
Per cent. passing	96.9%	85.6%	72.4%
Per cent. residue	3.1%	14.4%	27.6%

The material, therefore, is so coarsely ground that only a trifle over 85 per cent. passes a 100-mesh sieve.

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*Twentieth Ann. Rept. U. S. Geol. Surv., Pt. 6, p. 545.

*Journal Amer. Chem. Soc., vol. 25.

GRINDING AND MIXING—SLAG-LIMESTONE MIXTURES.—While the manufacture of Portland cement from a mixture of slag and limestone is similar in general theory and practice to its manufacture from a limestone-clay mixture, certain interesting difference occur in the preparation of the mixture. In the following paragraphs the general methods of preparing mixtures of slag and limestone for use in Portland cement manufacture will first be noted, after which certain processes peculiar to the use of this particular mixture will be described separately.

General methods.—After it had been determined that the pozzuolanic cement made* by mixing slag with lime without subsequent burning of the mixture, was not an entirely satisfactory structural material, attention was soon directed toward the problem of making a true Portland cement from such slag. The blast-furnace slags commonly available, while carrying enough silica and alumina for a cement mixture, are too low in lime to be suitable for Portland cement. Additional lime must be added, usually in the form of limestone; the slag and limestone must be well mixed and the mixture properly burned. The general methods for accomplishing the proper mixture of the materials vary in details. It seems probable that the first method used in attempting to make a true Portland cement from slag, was to dump the proper proportion of limestone, broken into small lumps, into molten slag. The idea was that both mixing and calcination could thus be accomplished in one stage; but in practice it was found that the resulting cement was variable in composition and always low in grade. This method has accordingly fallen into disuse, and at present three different general processes of preparing the mixture are practiced at different European and American plants.

1. The slag is granulated, dried, and ground, while the limestone is dried and ground separately. The two materials are then mixed in proper proportions, the mixture is finely pulverized in tube mills, and the product is fed in a powdered state to rotary kilns.

2. The slag is granulated, dried, and mixed with slightly less than the calculated proper amount of limestone, which has been previously dried and powdered. To this mixture is added

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*See Municipal Engineering, vol. 24, p. 335, May, 1903.

sufficient powdered slaked lime (say 2 to 6 per cent.) to bring the mixture up to correct composition. The intimate mixture and final reduction are then accomplished in ball and tube mills. About 8 per cent. of water is then added, and the slurry is made into bricks, which are dried and burned in a dome or chamber kiln.

3. Slag is granulated and mixed, while still wet, with crushed limestone in proper proportions. This mixture is run through a rotary calciner, heated by waste kiln gases, in which the temperature is sufficient not only to dry the mixture, but also to partly powder it, and to reduce most of the limestone to quicklime. The mixture is then pulverized and fed into rotary kilns.

Of the three general processes above described, the second is unsuited to American conditions. The first and third are adapted to the use of the rotary kiln. The third seems to be the most economical, and has given remarkably low fuel consumption in practice, but so far has not been taken up in the United States.

Certain points of manufacture peculiar to the use of mixtures of slag and limestone will now be described.

Composition of the slag.—The slags available for use in Portland cement manufacture are of quite common occurrence in iron-producing districts. Those best suited for such use are the more basic blast-furnace slags, and the higher such slags run in lime the more available they are for this use. The slags utilized will generally run from 30 to 40 per cent. lime. The presence of over 3 per cent. or so of magnesia in a slag is of course enough to render its use as a Portland cement material inadvisable; and on this account slags from furnaces using dolomite (magnesian limestone) as a flux, are unsuited for cement manufacture. The presence of any notable percentage of sulphur is also a drawback, though, as will be later noted, part of the sulphur in the slag will be removed during the process of manufacture.

Granulation of slag.—If slag be allowed to cool slowly it solidifies into a dense, tough material, which is not readily reduced to the requisite fineness for a cement mixture. If it be cooled suddenly, however, as by bringing the stream of molten slag into contact with cold water, the slag is "granulated," *i. e.*, it breaks up into small porous particles. This granulated slag or "slag sand" is much more readily pulverized than a slowly cooled slag; its sudden cooling has also intensified the chemical activity of its constituents so as to give it hydraulic properties, while part of the sulphur contained in the original slag has been removed. The sole disadvantage of the process of granulating slag is that the product contains 20 to 40 per cent. of water, which must be driven off before the granulated slag is sent to the grinding machinery.

In practice the granulation of the slag is effected by directing the stream of molten slag direct from the furnace into a sheet-iron through. A small stream of water flows along this trough, the quantity and rate of flow of the water being regulated so as to give complete granulation of the slag without using an excessive amount of water. The trough may be so directed as to discharge the granulated slag into tanks or into box cars, which are usually perforated at intervals along the sides so as to allow part of the water to drain off.

Drying the slag.—As above noted, the granulated slag may carry from 20 to 40 per cent. of water. This is removed by treating the slag in rotary dryers. In practice such driers give an evaporation of 8 to 10 pounds of water per pound of coal. The practice of slag drying is very fully described in Vol. 10 of the Mineral Industry, pages 84-95, where figures and descriptions of various driers are also given, with data on their evaporative efficiency. As noted earlier in this article, one of the methods of manufacturing Portland cement from slag puts off the drying of the slag until after it has been mixed with the limestone, and then accomplishes the drying by utilizing waste heat from the kilns. Kiln gases could of course be used anyway in the slag driers, but it so happens that they have not been so used except in plants following the method in question.

Grinding the slag.—Slag can be crushed with considerable ease to about 50 mesh, but notwithstanding its apparent brittleness it is difficult to grind it finer. Until the introduction of the tube mill in fact it was almost impossible to reduce this material to the fineness necessary for a cement mixture, and the proper grinding of the slag is still an expensive part of the process, as compared with the grinding of limestone, shales, or clay.

Composition of the limestone.—As the slag carries all the silica and alumina necessary for the cement mixture, the limestone to be added to it should be simply a pure lime carbonate.

The limestone used for flux at the furnace which supplies the slag will usually be found to be of suitable composition for use in making up the cement mixture.

Economics of using slag-limestone mixtures.—The manufacture of a true Portland cement from a mixture of slag and limestone presents certain undoubted advantages over the use of any other raw materials, while it has also a few disadvantages.

Probably the most prominent of the advantages lies in the fact that the most important raw material—the slag—can usually be obtained more cheaply than an equal amount of natural raw material could be quarried or mined. The slag is a waste product, and a troublesome material to dispose of, for which reasons it is obtained at small expense to the cement plant. Another advantage is due to the occurrence of the lime in the slag as oxide, and not as carbonate. The heat necessary to drive off the carbon dioxide from an equivalent mass of limestone is therefore saved when slag forms part of the cement mixture, and very low fuel consumption is obtained when slag-limestone mixture is burned.

Of the disadvantages, the toughness of the slag and the necessity for drying it before grinding are probably the most important. These serve to partly counterbalance the advantages noted above. A third difficulty, which is not always apparent at first, is that of securing a proper supply of suitable slag. Unless the cement plant is closely connected in ownership with the furnaces from which its slag supply is to be obtained, this difficulty may become very serious. In a season when a good iron market exists the furnace manager will naturally give little thought to the question of supplying slag to an independent cement plant.

The advantages of the mixture, however, seem to outweigh its disadvantages, for the manufacture of Portland cement from slag is now a large and growing industry in both Europe and America. Two Portland cement plants using slag and limestone as raw materials have been established for some time in this country, several others are in course of construction at present, and it seems probable that in the near future Alabama will join Illinois and Pennsylvania as an important producer of Portland cement from slag.

GRINDING AND MIXING—WET METHODS.—Wet methods of preparing Portland cement mixtures date back to the time when millstones and similar crude grinding contrivances were in use. With such imperfect machinery it was almost impossible to grind dry materials fine enough to give a good Portland cement mixture. The advent of good grinding machinery has practically driven out wet methods of manufacture in this country, except in dealing with materials such as marls, which naturally carry a large percentage of water. One or two plants in the United States do, it is true, deliberately add water to a limestone-clay mixture; but the effect of this practice on the cost sheets of these remarkable plants is not encouraging.

In preparing cement mixtures from marl and clay, a few plants dry both materials before mixing. It seems probable that this practice will spread, for the wet method of mixture is inherently expensive. At present, however, almost all marl plants use wet methods of mixing, and it is therefore necessary to give some space to a discussion of such methods.

Certain points regarding the location, physical condition, and chemical composition of the marls and clays used in such mixtures have important effects upon the cost of the wet process. As regards location, considered on a large scale, it must be borne in mind that marl deposits of workable size occur only in the Northern States and in Canada. In consequence the climate is unfavorable to continuous working throughout the year, for the marl is usually covered with water, and in winter it is difficult to secure the material. In a minor sense location is still an important factor, for marl deposits necessarily and invariably are found in depressions; and the mill must, therefore, just as necessarily, be located at a higher level than its source of raw material, which involves increased expense in transporting the raw material to the mill.

Glacial clays, which are usually employed in connection with marl, commonly carry a much larger proportion of sand and pebbles than do the sedimentary clays of more southern regions.

The effect of the water carried by the marl has been noted on an earlier page. The material as excavated will consist approximately of equal weights of lime carbonate and of water. This on the face of it would seem to be bad enough as a business proposition; but we find that in practice more water is often added to permit the marl to be pumped up to the mill.

On the arrival of the raw materials at the mill the clay is often dried, in order to simplify the calculation of the mixture. The reduction of the clay is commonly accomplished in a disintegrator or in edge-runner mills, after which the material is further reduced in a pug mill, sufficient water being here added to enable it to be pumped readily. It is then ready for mixture with the marl, which at some point in its course has been screened to remove stones, wood, etc., so far as possible. The slurry is further ground in pug mills or wet grinding mills of the disk type; while the final reduction takes place commonly in wet tube mills. The slurry, now containing 30 to 40 per cent. of solid matter and 70 to 60 per cent. of water, is pumped into storage tanks, where it is kept in constant agitation to avoid settling. Analyses of the slurry are taken at this point, and the mixture in the tanks is corrected if found to be of unsatisfactory composition. After standardizing, the slurry is pumped into the rotary kilns. Owing to the large percentage of water contained in the slurry the fuel consumption per barrel of finished cement is 30 to 50 per cent. greater, and the output of each kiln correspondingly less than in the case of a dry mixture.

It may be of interest, for comparison with the above description of the wet process with rotary kilns, to insert a description of the semi-wet process as carried on a few years ago at the dome kiln plant of the Empire Portland Cement Company at Warners, N. Y. The plant has been remodeled since that date, but the processes formerly followed are still of interest, as they resulted in a high-grade though expensive product.

At the Empire plant the marl and clay were obtained from a swamp about three-fourths of a mile from the mill. A revolving derrick with clam-shell bucket was employed for excavating the marl, while the clay was dug with shovels. The materials were taken to the works over a private narrow-gauge road, on cars, carrying about three tons each, drawn by a small locomotive. At the mill the cars were hauled up an inclined track, by means of a cable and drum, to the mixing floor.

The clay was dried in three Cummer "Salamander" driers, after which it was allowed to cool, and then carried to the mills. These mills were of the Sturtevant "rock emery" type, and reduced the clay to a fine powder, in which condition it was fed, after being weighed, to the mixer. The marl was weighed and sent directly to the mixer, no preliminary treatment being necessary. The average charge was about 25 per cent. clay and about 75 per cent. marl.

The mixing was carried on in a mixing pan 12 feet in diameter, in which two large rolls, each about 5 feet in diameter, and 16-inch face, ground and mixed the materials thoroughly. The mixture was then sampled and analyzed, after which it was carried by a belt conveyor to two pug mills, where the mixing was completed and the slurry formed into slabs about 3 feet long and 4 to 5 inches in width and height. These on issuing from the pug mill were cut into a number of sections, so as to give bricks about 6 inches by 4 inches by 4 inches in size. The bricks were then placed on slats, which were loaded on rack cars and run into the drying tunnels. The tunnels were heated by waste gases from the kilns and required from twenty-four to thirty-six hours to dry the bricks.

After drying the bricks were fed into dome kilns, twenty of which were in use, being charged with alternate layers of coke and slurry bricks. The coke charge for a kiln was about four or five tons, and this produced 20 to 26 tons of clinker at each burning, thus giving a fuel consumption of about 20 per cent. as compared with the 40 per cent. or so required in the rotary kilns using wet materials. From thirty-six to forty hours were required for burning the charge. After cooling, the clinker was shoveled out, picked over by hand, and reduced in a Blake crusher, Smidth ball mills, and Davidsen tube mills.

Composition of mixture.—The cement mixture ready for burning will commonly contain from 74 to 77.5 per cent. of lime carbonate, or an equivalent proportion of lime oxide. Several analyses of actual cement mixtures are given in the following table. Analysis No. 1, with its relatively high percentage of magnesia, is fairly typical of Lehigh Valley practice. Analyses Nos. 2 and 3 show mixtures low in lime, while analysis No. 4 is probably the best proportioned of the four, especially in regard to the ratio between silica and alumina plus iron. This ratio, for ordinary purposes, should be about 3.-, as the cement becomes quicker setting and lower in ultimate strength as the percentage of alumina increases. If the alumina percentage be carried too high, moreover, the mixture will give a fusible, sticky clinker when burned, causing trouble in the kilns.

Analyses of cement mixtures.

	1	2	3	4
Silica	12.62	13.46	13.85	11.77
Alumina and iron oxide	6.00	?	7.20	4.35
Carbonate of lime	75.46	73.66	73.93	76.84
Magnesia	2.65	?	?	1.74

BURNING THE MIXTURE.

After the cement mixture has been carefully prepared, as described in preceding pages, it must be burned with equal care. In the early days of the Portland cement industry a simple vertical kiln, much like that used for burning lime and natural cement, was used for burning the Portland cement mixture. These kilns, while fairly efficient so far as fuel consumption was concerned, were expensive in labor, and their daily output was small. In France and Germany they were soon supplanted by improved types, but still stationary and vertical, which gave very much lower fuel consumption. In America, however, where labor is expensive while fuel is comparatively cheap, an entirely different style of kiln has been evolved. This is the rotary kiln. With the exception of a very few of the older plants, which have retained vertical kilns, all American Portland cement plants are now equipped with rotary kilns.

The history of the gradual evolution of the rotary kiln is of great interest, but as the subject can not be taken up here, reference should be made to the papers cited below* in which details, accompanied often by illustrations of early types of rotary kilns are given.

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*Duryee, E., The first manufacture of Portland cement by the direct rotary kiln process. Engineering News. July 26, 1900.

Lesley, R. W., History of the Portland cement industry in the United States. 8 vo. pp. 146, Philadelphia. 1900.

Lewis, F. H., The American rotary kiln process for Portland cement, in The Cement Industry, pp. 188-199, New York, 1900.

Matthey, H., The invention of the new cement burning method. Engineering and Mining Journal, vol. 67, pp. 555, 705; 1899.

Stanger, W. H., and Blount, B., The rotary process of cement manufacture. Proc. Institution Civil Engineers, vol. 145, pp. 44-136; 1901.

Editorial, The influence of the rotary kiln on the development of Portland cement manufacture in America. Engineering News, May 3, 1900.

The design, construction and operation of the vertical stationary kilns of various types is discussed in many reports in Portland cement, the most satisfactory single paper being probably that referred to below*. As the subject is, in America at least, a matter of simply historical interest, no description of these kilns or their operation will be given in the present bulletin.

At present, practice in burning at the different American cement plants is rapidly approaching uniformity, though differences in materials, etc., will always prevent absolute uniformity from being reached. The kiln in which the material is burned is now almost invariably of the rotary type, the rotary process, which is essentially American in its development, being based upon the substitution of machines for hand labor wherever possible. A brief summary of the process will first be given, after which certain subjects of interest will be taken up in more detail.

Summary of burning process.—As at present used, the rotary kiln is a steel cylinder about 6 feet in diameter; its length, for dry materials, is usually 60 or 80 feet, while for wet mixtures an 80-foot, or even longer, kiln is frequently employed.

This cylinder is set in a slightly inclined position, the inclination being approximately one-half inch to the foot. The kiln is lined, except near the upper end, with very resistant fire brick, to withstand both the high temperature to which its inner surface is subjected and also the destructive action of the molten clinker.

The cement mixture is fed in at the upper end of the kiln, while fuel (which may be either powdered coal, oil, or gas), is injected at its lower end. The kiln, which rests upon geared bearings, is slowly revolved about its axis. This revolution, in connection with the inclination at which the cylinder is set, gradually carries the cement mixture to the lower end of the kiln. In the course of this journey the intense heat generated by the burning fuel first drives off the water and carbon dioxide from the mixture, and then causes the lime, silica, alumina, and

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*Stanger, W. H., and Blount, B., Gilbert, W., and Candlot, E., (**Discussion of the value, design and results obtained from various types of fixed kilns**). Proc. Institution Civil Engineers, vol. 145, pp. 44, 48, 81, 82, 99, 100; 1901.

iron to combine chemically to form the partially fused mass known as "cement clinker." This clinker drops out of the lower end of the kiln, is cooled so as to prevent injury to the grinding machinery, and is then sent to the grinding mills.

Theoretical fuel requirements.—As a preliminary to a discussion of actual practice in the matter of fuel, it will be of interest to determine the heat units and fuel theoretically required in the manufacture of Portland cement from a dry mixture of normal composition.

In burning such a mixture to a clinker, practically all of the heat consumed in the operation will be that required for the dissociation of the lime carbonate present into lime oxide and carbon dioxide. Driving off the water of combination that is chemically held by the clay or shale, and decomposing any calcium sulphate (gypsum) that may be present in the raw materials, will require a small additional amount of heat. The amount required for these purposes is not accurately known, however, but is probably so small that it will be more or less entirely offset by the heat which will be liberated during the combination of the lime with the silica and alumina. We may, therefore, without sensible error, regard the total heat theoretically required for the production of a barrel of Portland cement as being that which is necessary for the dissociation of 450 pounds of lime carbonate. With coal of a thermal value of 13,500 B. T. U., burned with only the air supply demanded by theory, this dissociation will require 25½ pounds of coal per barrel of cement, a fuel consumption of only 6.6 per cent.

Losses of heat in practice.—In practice with the rotary kiln, however, there are a number of distinct sources of loss of heat, which result in a fuel consumption immensely greater than the theoretical requirements given above. The more important of these sources of loss are the following:

1. The kiln gases are discharged at a temperature much above that of the atmosphere, ranging from 300°F. to 2,000°F., according to the type of materials used and the length of the kiln.
2. The clinker is discharged at a temperature varying from 300°F. to 2,500°F., the range depending, as before, on materials and length of the kiln.

3. The air supply injected into the kiln is always greater, and usually very much greater, than that required for the perfect combusion of the fuel; and the available heating power of the fuel is thereby reduced.

4. Heat is lost by radiation from the ends and exposed surfaces of the kiln.

5. The mixture, in plants using a wet process, carries a high percentage of water, which must be driven off.

It is evident, therefore, that present-day working conditions serve to increase greatly the amount of fuel actually necessary for the production of a barrel of cement above that required by theory.

Actual fuel requirements and output.—Rotary kilns are nominally rated at a production of 200 barrels per day per kiln. Even on dry and easily clinkered materials and with good coal, however, such an output is not commonly attained with a 60-foot kiln, except in the Lehigh district. Normally a kiln working on a dry mixture will produce from 160 to 180 barrels of cement per day of twenty-four hours. In doing this, if good coal is used, its fuel consumption will commonly be from 120 to 140 pounds of coal per barrel of cement, though it may range as high as 160 pounds, and, on the other hand, has fallen as low as 90 pounds. An output of 175 barrels per day, with a coal consumption of 130 pounds per barrel, may therefore be considered as representing the results of fairly good practice on dry materials with a 60-foot kiln. In dealing with a wet mixture, which may carry anywhere from 30 to 70 per cent. of water, the results are more variable, though always worse than with dry materials. In working a 60-foot kiln on wet material, the output may range from 80 to 120 barrels per day, with a fuel consumption of from 150 to 230 pounds per barrel. Using a longer kiln, partly drying the mixture, and utilizing waste heat, will of course improve these figures materially.

When the heavy Western oils are used for kiln fuel, it may be considered that one gallon of oil is equivalent in the kiln to about ten pounds of coal. The fuel consumption, using dry materials, will range between 11 and 14 gallons of oil per barrel of cement; but the output per day is always somewhat less with oil fuel than where coal is used.

Natural gas in the kiln may be compared with good Pennsylvania coal by allowing about 20,000 to 30,000 cubic feet of gas as equivalent to a ton of coal. This estimate is, however, based upon too little data to be as close as those above given for oil or coal.

Effect of composition on burning.—The differences in composition between Portland cement mixtures are very slight if compared, for example, to the differences between various natural cement rocks. But even such slight differences as do exist exercise a very appreciable effect on the burning of the mixture. Other things being equal, any increase in the percentage of lime in the mixture will necessitate a higher temperature in order to get an equally sound cement. A mixture which will give a cement carrying 59 per cent. of lime, for example, will require much less thorough burning than would a mixture designed to give a cement with 64 per cent. of lime.

With equal lime percentages, the cement carrying high silica and low alumina and iron will require a higher temperature than if it were lower in silica and higher in alumina and iron. But, on the other hand, if the alumina and iron are carried too high, the clinker will ball up in the kiln, forming sticky and unmanageable masses.

Character of kiln coal.—The fuel most commonly used in modern rotary kiln practice is bituminous coal, pulverized very finely. Coal for this purpose should be high in volatile matter, and as low in ash and sulphur as possible. Russell gives the following analyses of West Virginia and Pennsylvania coals used at present at various cement plants in Michigan.

Analyses of kiln coals.

	1	2	3	4
Fixed carbon	56.15	56.33	55.82	51.69
Volatile matter	35.41	35.26	39.37	39.52
Ash	6.36	7.06	3.81	6.13
Moisture	2.08	1.35	1.00	1.40
Sulphur	1.30	1.34	0.42	1.46

The coal as usually bought is either "slack" or "run of mine." In the latter case it is necessary to crush the lumps before proceeding further with the preparation of the coal, but with slack this preliminary crushing is not necessary, and the material can go directly to the dryer.

Drying coal.--Coal as bought may carry as high as 15 per cent. of water in winter or wet season. Usually it will run from 3 to 8 per cent. To secure good results from the crushing machinery it is necessary that this water should be driven off. For coal drying, as for the drying of raw materials, the rotary dryer seems best adapted to American conditions. It should be said, however, that in drying coal it is usually considered inadvisable to allow the products of combustion to pass through the cylinder in which the coal is being dried. This restriction serves to decrease slightly the possible economy of the dryer, but an evaporation of 6 to 8 pounds of water per pound of fuel coal can still be counted on with any good dryer. The fuel cost of drying coal containing 8 per cent. of moisture, allowing $2 per ton for the coal used as fuel, will therefore be about 3 to 4 cents per ton of dried product.

Pulverizing coal.—Though apparently brittle enough when in large lumps, coal is a difficult material to pulverize finely. For cement kiln use, the fineness of reduction is very variable. The finer the coal is pulverized the better results will be obtained from it in the kiln; and the poorer the quality of the coal the finer it is necessary to pulverize it. The fineness attained may therefore vary from 85 per cent. through a 100-mesh sieve, to 95 per cent. or more, through the same. At one plant a very poor but cheap coal is pulverized to pass 98 per cent. through a 100-mesh sieve, and in consequence gives very good results in the kiln.

Coal pulverizing is usually carried on in two stages, the material being first crushed to 20 to 30 mesh in a Williams mill or ball mill, and finally reduced in a tube mill. At many plants, however, the entire reduction takes place in one stage, Griffin or Huntington mills being used.

Total cost of coal production.—The total cost of crushing (if necessary), drying and pulverizing coal, and of conveying and feeding the product to the kiln, together with fair allowance for replacements and repairs, and for interest on the plant, will probably range from about 20 to 30 cents per ton of dried coal, for a 4-kiln plant. This will be equivalent to a cost of from 3 to 5 cents per barrel of cement. While this may seem a heavy addition to the cost of cement manufacture, it should be remembered that careful drying and fine pulverizing enable the manufacturer to use much poorer—and therefore cheaper—grades of coal than could otherwise be utilized.

CLINKER GRINDING. GYPSUM.

Clinker grinding.—The power and machinery required for pulverizing the clinker at a Portland cement plant using the dry process of manufacture is very closely the same as that required for pulverizing the raw materials for the same output. This may seem, at first sight, improbable, for Portland cement clinker is much harder to grind than any possible combination of raw materials; but it must be remembered that for every barrel of cement produced about 600 pounds of raw materials must be pulverized, while only a scant 400 pounds of clinker will be treated, and that the large crushers required for some raw materials can be dispensed with in crushing clinker. With this exception, the raw material side and the clinker side of a dry-process Portland cement plant are usually almost or exactly duplicates.

The difficulty, and in consequence the expense, of grinding clinker will depend in large part on the chemical composition of the clinker and on the temperature at which it has been burned. The difficulty of grinding, for example, increases with the percentage of lime carried by the clinker; and a clinker containing 64 per cent. of lime will be very noticeably more resistant to pulverizing than one carrying 62 per cent. of lime. So far as regards burning, it may be said in general, that the more thoroughly burned the clinker the more difficult it will be to grind, assuming that its chemical composition remains the same.

The tendency among engineers at present is to demand more finely ground cement. While this demand is doubtless justified by the results of comparative tests of finely and coarsely ground cements, it must be borne in mind that any increase in fineness of grinding means a decrease in the product per hour of the grinding mills employed, and a consequent increase in the cost of cement. At some point in the process, therefore, the gain in strength due to fineness of grinding will be counterbalanced by the increased cost of manufacturing the more finely ground product.

The increase in the required fineness has been gradual but steady during recent years. Most specifications now require at least 90 per cent. to pass a 100-mesh sieve; a number require 92 per cent.; while a few important specifications require 95 per cent. Within a few years it is probable that almost all specifications will go as high as this.

Addition of gypsum.—The cement produced by the rotary kiln is invariably naturally so quick-setting as to require the addition of sulphate of lime. This substance, when added in quantities up to 2½ or 3 per cent., retards the rate of set of the cement proportionately, and appears to exert no injurious influence on the strength of the cement. In amount over 3 per cent., however, its retarding influence seems to become at least doubtful, while a decided weakening of the cement is noticeable.

Sulphate of lime may be added in one of two forms: either as crude gypsum or as burned plaster. Crude gypsum is a natural hydrous lime sulphate, containing about 80 per cent. of lime sulphate and 20 per cent. of water. When gypsum is calcined at temperatures not exceeding 400°F., most of its contained water is driven off. The "plaster" remaining carries about 93 per cent. of lime sulphate, with only 7 per cent of water.

In Portland cement manufacture either gypsum or burned plaster may be used to retard the set of the cement. As a matter of fact, gypsum is the form almost universally employed in the United States. This is merely a question of cost. It is true that to secure the same amount of retardation of set it will be necessary to add a little more of gypsum than if burned plaster were used; but, on the other hand, gypsum is much cheaper than burned plaster.

The addition of the gypsum to the clinker is usually made before it has passed into the ball mill, komminuter, or whatever mill is in use for preliminary grinding. Adding it at this point secures much more thorough mixing and pulverizing than if the mixture were made later in the process. At some of the few plants which use plaster instead of gypsum, the finely ground plaster is not added until the clinker has received the final grinding and is ready for storage or packing.

CONSTITUTION OF PORTLAND CEMENT.

During recent years much attention has been paid by various investigators to the constitution of Portland cement. The chemical composition of any particular sample can, of course, be readily determined by analysis; and by comparison of a number of such analyses, general statements can be framed as to the range in composition of good Portland cements.

The chemical analyses will determine what ingredients are present, and in what percentages, but other methods of investigation are necessary to ascertain in what manner these various ingredients are combined. A summary of the more important results brought out by these investigations on the constitution of Portland cement is here given.

It would seem to be firmly established that, in a well-burned Portland cement, much of the lime is combined with most of the silica to form the compound $3\ CaO, SiO_2$,—tricalcic silicate. To this compound is ascribed, in large measure, the hydraulic properties of the cement; and in general it may be said that the value of a Portland cement increases directly as the proportion of $3\ CaO, SiO_2$. The ideal Portland cement, toward which cements as actually made tend in composition, would consist exclusively of tricalcic silicate, and would be therefore composed entirely of lime and silica in the following proportions:

Lime (CaO)	73.6
Silica (SiO_2)	26.4

Such an ideal cement, however, can not be manufactured under present commercial conditions, for the heat required to clinker such a mixture can not be attained in any working kiln. Newberry has prepared such mixtures by using the oxy-hydrogen blowpipe; and the electrical furnace will also give clinker of this composition; but a pure lime-silica Portland is not possible under present-day conditions.

In order to prepare Portland cement in actual practice, therefore, it is necessary that some other ingredient or ingredients should be present to serve as a flux in aiding the combination of the lime and silica, and such aid is afforded by the presence of alumina and iron oxide.

Alumina (Al_2O_3) and iron oxide (Fe_2O_3), when present in noticeable percentages, serve to reduce the temperature at which combination of the lime and silica (to form $3\ CaO, SiO_2$) takes place; and this clinkering temperature becomes further and further lowered as the percentages of alumina and iron are increased. The strength and value of the product, however, also decrease as the alumina and iron increase; so that in actual practice it is necessary to strike a balance between the advantage of low clinkering temperature and the disadvantage of weak cement, and to thus determine how much alumina and iron should be used in the mixture.

It is generally considered that whatever alumina is present in the cement is combined with part of the lime to form the compound $2\ CaA, SiO_2$,—dicalcic aluminate. It is also held by some, but this fact is somewhat less firmly established than the last, that the iron present is combined with the lime to form the compound $2\ CaO, Fe_2O_3$. For the purposes of the present paper, it will be sufficient to say that, in the relatively small percentages in which iron occurs in Portland cement, it may for convenience be considered as almost equivalent to alumina and its action, and the two may be calculated together.

PART II.

THE CEMENT RESOURCES OF ALABAMA.

BY EUGENE A. SMITH.

In Alabama is found an extensive series of limestones capable of furnishing excellent raw material for the manufacture of Portland cement, while the shales and clays necessary to complete the mixture are found in every county in the State. As a matter of convenience, the Portland cement materials of northern Alabama and of central and southern Alabama will be discussed separately, because there is a marked geologic as well as geographic distinction between the two portions of the State.

CHAPTER 1.

THE PORTLAND CEMENT MATERIALS OF NORTHERN ALABAMA.

The raw materials for the manufacture of Portland cement occurring in the Paleozoic formations of northern Alabama are limestones, shales, and clays. Of these the limestones belong mainly to the Lower Carboniferous and the Trenton formations; the shales to the Coal Measures, and the clays to the Cambrian, Lower Carboniferous, and Coal Measures. Although as yet these materials have not been utilized for this purpose in Alabama, they have been so used in other States, and there is no reason to doubt that the future will witness their utilization in Alabama.

AVAILABLE LIMESTONES.

General geology.—In northern Alabama the combined effects of geologic structure and erosion have resulted in certain definite topographic types, with which the geologic outcrops are closely connected.

Structurally northern Alabama is made up of a series of parallel synclines and anticlines, trending usually a little north of east. The anticlines are sharp, narrow folds; the synclines are flat, wide basins. The effect of erosion has been to cut away the anticlines and the streams of the region now run along anticlinal valleys bordered by flat-topped synclinal plateaus.

The plateaus throughout most of northern Alabama are capped by conglomerates, shales, and sandstones of the Coal Measures. The lower Carboniferous limestones commonly outcrop along the sides and at the immediate base of the plateaus. The lower Silurian beds occur as long, narrow outcrops in the valleys. The middle of the valley is usually occupied by Cambrian shales and the Knox dolomite. The Trenton limestones would normally outcrop as two parallel bands in each valley—between the middle of the valley and the foothills of the plateaus. Faulting has, however, been so common that only one of these bands is usually present, the other being cut out by a fault.

Lower Carboniferous.—Limestones of suitable quality for cement manufacture occur in the Mountain limestone or Chester formation of the lower Carboniferous. Perhaps the most accessible occurrences of this rock are in the Tennessee Valley to the west of Tuscumbia and south of the river and railroad. Here the quarries of Fossick & Co. were formerly located. Their quarries at this time are farther eastward, but at a greater distance from the river, in Lawrence county north of Russellville. This outcrop extends thence eastward along the base of Little Mountain as far as Whitesburg, above which place to Guntersville the river flows through a valley floored with lower Carboniferous limestone. The Southern Railway passes over outcrops of this rock in most of the mountain coves east of Huntsville, and from Scottsboro to the Tennessee line the country rock is almost entirely of this formation. The Louisville and Nashville Railroad south of Decatur nearly to Wilhite is mostly in the same formation. These two lines, together with the Tennessee river, would provide ample means of transportation for the rock or for the finished product. Analysis of the rock from the Fossick quarries is given in Table A.

In Browns Valley south of Brooksville the Mountain limestone is the prevailing rock across the valley, and at Bangor and Blount Springs, on the Louisville and Nashville Railroad, there are extensive quarries which have been worked for many years to supply rock for fluxing purposes to the furnaces of the Birmingham district. Analyses Nos. 2, 3, 4, 5, 6, 7, 8, and 9, Table A, show the composition of average samples from these quarries; 5 to 9, inclusive, are of carload samples.

From Brooksville to the Tennessee line a great thickness of this limestone is exposed along the western escarpment of Sand Mountain, below the sandstones of the Coal Measures, which there cap the mountain. In this area the river runs near the foot of the mountain and would afford the means of transportation.

In similar manner the lower Carboniferous limestone outcrops along the western flank of Lookout Mountain in Little Wills Valley, from near Attalla to the Georgia line, and south of Attalla it forms the lower part of the escarpments of Blount and Chandlers Mountains. The Alabama Great Southern Railroad passes very near to the outcrop from the Georgia line down to Springville, Ala. South of Springville large outcrops occur in Shades Valley, and at Trussville are quarries which have supplied the Birmingham furnaces. Analyses 10 to 17, inclusive, Table A, are of material from Trussville; and analyses 12 to 17, inclusive, represent average samples from carload lots delivered to the furnace.

In Murphrees Valley the main outcrop of this rock is on the western side, and quarries at Compton have for many years been worked to supply the Birmingham furnaces. Analyses 18, 19, and 20, Table A, of the rock from these quarries show somewhat varying composition, but by proper selection suitable material could be easily obtained.

In the valleys lying east of Shades Valley and in parts of Shades Valley itself this formation becomes one of prevailing shales and sandstones and the limestones are of limited occurrence and of inferior quality.

Trenton limestone.—The Trenton limestone outcrops in Alabama in three principle areas. In the Tennessee River Valley some of the smaller streams which flow into the river from the north, like Flint River, Limestone Creek, Elk River, Bluewater Creek, and Shoal Creek, have eroded their valleys into the Trenton limestone. These areas are crossed at only a few points by the railroads leading out from Huntsville and Florence, and no commercial use has yet been made of the rock.

In the narrow anticlinal valleys below enumerated erosion has in most cases sunk the floors of the valleys into Cambrian strata, and, as a consequence, the Trenton limestone occupies a narrow belt on each side, near the base of the Red Mountain ridges. But since a fault usually occurs on one side of these valleys, the Red Mountain ridges and the accompanying Trenton limestone are more fully represented on the unfaulted side, which is the eastern side in all except Murphrees Valley. While the Trenton forms practically a continuous belt along the undisturbed side, extensive areas are sometimes found on the faulted side also. This is the case, for instance, at Vance, on the Alabama Great Southern Railroad, where the rock is quarried for flux for the furnace of the Central Iron Company at Tuscaloosa. Analysis 1 of Table B, shows its composition here. Other series of analyses from lower ledges in the quarry show only 1.22 per cent of silica, but more magnesia.

In cases where erosion has not gone so deep as to reach the Cambrian the Trenton may be found extending entirely across the valleys. This is the case in the lower part of Browns Valley from Brooksville to beyond Guntersville. Above Guntersville the Trenton is seen mainly on the eastern side of the valley. The river touches these outcrops at many points, and at Guntersville the railroad connecting that city with Attalla would afford an additional means of transportation. No developments have yet been made in this area.

The valley separating the Warrior from the Cahaba coal field is known as Roups Valley in the southern and as Jones Valley in the northern part. In these the Trenton occupies a narrow, continuous belt, usually near the base of the eastern Red Mountain ridge, though in places it is high up on the ridge and even at its summit, as at Gate City, where the quarries of the Sloss Iron Company are located. Many analyses of the rock from these quarries have been made, and several are given in Table B, (Nos, 2, 3, 4, 5, 6).

In Murphrees Valley the continuous belt of the Trenton, as above explained, is on the western side, while the faulted remnants are on the eastern side. No quarries have been opened in the Trenton limestone here, but the Louisville and Nashville Railroad goes up the valley as far as Oneonta and would afford means of transportation.

In the Cahaba Valley, which separates the Cahaba coal field from the Coosa coal field, the Trenton is well exposed on the eastern side for the entire length of the valley from Gadsden down. It expands into wide areas near the southern end, where it has been quarried for lime burning, at Pelham, Siluria, Longview, Calera, and other places on the line of the Louisville and Nashville road. Analyses 7, 8 and 9 of Table B, show the composition of the rock in this region.

The Central of Georgia and the Southern railroads cross this belt about midway of its length at Leeds, in Jefferson County, and near its northern end it is crossed by the Louisville and Nashville Railroad, where a quarry at Rock Springs, on the flank of Colvin Mountain, supplies the rock for lime burning. Anaylsis 10 shows the character of the rock at this point.

At Pratts Ferry, on the Cahaba River, a few miles above Centreville, in Bibb County, the Trenton limestone makes high bluffs along the river for several miles, and is in most convenient position for easy quarrying.

Marble works have in former days been established here and should be again put in operation, since the marble is of fine quality and beautifully variegated. No analyses are available, but there is no doubt that much of the rock is sufficiently low in magnesia to be fit for use in cement making. Cahaba River and a short spur from the Mobile and Ohio Railroad would afford transportation facilities for this deposit.

In Big Wills Valley, which separates Sand and Lookout mountains, the Trenton limestone occupies perhaps 25 square miles, but it is crossed only by the railroad connecting Gadsden with Guntersvlile. No anaylses are available.

In the great Coosa Valley region the Trenton outcrops are found mostly on the western border near the base of Lookout Mountain, as in Broomtown Valley, and in other valleys extending south toward Gadsden. While these belts have been utilized in the past for the old Gaylesville, Cornwall, and Round

Mountain furnaces, and possibly for some furnaces now in blast, no analyses are available.

Similarly, farther south, along this western border of the Coosa Valley, and running parallel with the Coosa coal field in Calhoun, St. Clair, and Shelby counties, there are numerous long narrow outcrops of Trenton limestone. The Calcis quarry of the Tennessee Coal, Iron and Railroad Company, on the Central of Georgia Railroad, near Sterritt, is upon one of these outcrops, and furnishes limestone with a very low and uniform percentage of silica and magnesia. Analyses 11, 12, 13, 14, 15, and 16 exhibit the quality of the rock as received at the Ensley Steel Works, but care is taken at the quarry to select ledges low in silica and magnesia, and the analyses therefore represent only the selected ledges and not the average run of the quarry as a whole.

Near Talladega Springs, Marble Valley, and Shelby are other occurrences of the rock, and a quarry a few miles east of Shelby furnace has for many years supplied that furnace with its flux. The quality of the material here is shown by analyses 17, 18, 19, and 20, Table B.

The Cambrian limestones contain generally a very considerable proportion of magnesia, and for this reason are not suited for Portland-cement manufacture, though admirably adapted for furnace stone.

Marbles.—Along the eastern border of the Coosa Valley, near its contact with the metamorphic rocks, there is a belt of limestone which, in places, is a white crystalline marble of great purity, as is shown by analyses 1 to 7, inclusive, of Table C. The Louisville and Nashville Railroad, from Calera to Talladega, passes close to this belt at many points. This marble has been quarried at several places for ornamental stone. It is mentioned here because it is near the railroad and completes the account of the limestone.

THE CLAYS.

The most important clays in the Paleozoic region occur in the Coal Measures, in the Lower Carboniferous, and in the Lower Silurian and Cambrian formations. But, inasmuch as a later formation—the Tuscaloosa of the Cretaceous—borders the Paleozoic on the west and south, and as it contains a great variety as well as abundance of clays, we shall include it here, although it is not one of the Paleozoics.

Coal Measures.—In this group are numerous beds of shale which have been utilized in the manufacture of vitrified brick and fire brick, but many of them will probably be adapted to cement making. A great body of these shales occurs in connection with the coal seams of the Horse Creek or Mary Lee group, in Jefferson and Walker counties, and in position where they are conventienly situated with reference to limestone and coal and also to transportation lines. They are therefore well worth the attention of those contemplating the location of cement plants.

On the property of Mr. W. H. Graves, near North Birmingham, overlying the coal seam mined by him, there are two beds of shale—one yellowish, the other gray. These two shales have been tested and analyzed, and their composition is shown in Nos. 1 and 2 of the Table D.

Similar shales are known to occur at Coaldale, in Jefferson County, at Pearce's Mills in Marion, and at Cedar Grove Coal Mines in Tuscaloosa. The Coaldale shale is manufactured into vitrified brick. The other two have not yet been utilized.

Analyses 3 and 4 of Table D will show the composition of the shales at Coaldale and Cedar Grove.

It may be of interest to note that Cedar Grove is, so far as yet known, the nearest place to the Gulf ports, where the three essentials in the manufacture of Portland cement, viz., limestone, shale and coal, occur together, and on a railroad.

So also most of the coal seams mined in Alabama rest upon clay beds which have not as yet been specially examined as to their fitness for cement making; but, in view of the proximity of the coal mines to the limestones, it might be worth while to investigate these underclays of the coal seams.

Lower Carboniferous.—Associated with the cherty limestones of the lowermost division of the Lower Carboniferous of some of the anticlinal valleys are beds of clay of excellent quality, much of it being of the nature of china clay.

Probably the best of the exposures of these clays are to be seen in Little Wills Valley, between Fort Payne and the Georgia border, and on the line of the Great Southern Railroad, where for many years quarries have been in operation in supplying the material for tile works and potteries. The clays lie near the base of the formation close above the black shale of the Devonian, and average about 40 feet in thickness, though in places they reach 200 feet. The clay beds alternate with seams of chert which are from 2 to 8 inches in thickness, while the clay beds vary from 12 to 18 inches. The upper half of the clay is more gritty than the lower half which often contains material suitable for the manufacture of the finer grades of porcelain ware. Analyses 5 to 8, in Table D, show the composition of several varieties of clay from this section.

Lower Silurian and Cambrian.—Associated with the cherty limestones and brown iron-ore beds of the formations above named—beds of fine white clay, much of it china clay—are not uncommon. Analysis 9 of the table shows the composition of a white clay from the brown ore bank at Rock Run, in Cherokee County, where the clay is about 30 feet in thickness. Analyses 10 and 11 are also from Rock Run. No. 12, from near Gadsden, No. 13, from Blount County, and No. 14 from Oxanna, in Calhoun County, are clays which seem to be adapted to cement making. While no great number of the clays of these formations have been analyzed, they are known to be widely distributed in Calhoun, Talladega, Jefferson, Tuscaloosa, and other counties in connection with the brown ore deposits.

Cretaceous.—In many respects the most important formation of Alabama, in respect of its clays, is the lowermost division of the Cretaceous, which has been called the Tuscaloosa, and which is in part at least of the same geologic horizon as that of the Raritan clays of New Jersey. The prevailing strata of this formation are yellowish and grayish sands, but subordinated to them are great lenses of massive clay varying in quality from almost pure-white burning clay to dark-purple and mottled varieties high in iron.

The formation occupies a belt of country extending from the north-western corner of the State, around the edges of the Paleozoic formations to the Georgia line at Columbus. Its greatest width is at the northwest boundary of the State where it covers an area 30 or 40 miles wide in Alabama, and of about the same width in Mississippi. The breadth at Wetumpka and thence eastward to the Georgia line is only a few miles. The most important part of this belt is where it is widest in Elmore, Bibb, Tuscaloosa, Pickens, Fayette, Marion, Lamar, Franklin, and Colbert counties, and the deposits are traversed by the lines of the Mobile and Ohio; the Alabama Great Southern; the Louisville and Nashville; the Southern; and the Kansas City, Memphis and Birmingham railroads; as well as by the Warrior and Tombigbee rivers.

These clays have been described in some detail, and many analyses and physical tests have been presented in the Bulletin No. 6 of the Alabama Geological Survey. From this bulletin have been selected the analyses which appear to indicate the fitness of the clays for cement making.

In Elmore county, in the vicinity of Coosada, along the banks of the river, about Robinson Springs, Edgewood, and Chalk Bluff, there are many occurrences of these clays, some of which have been used in potteries for many years. Analyses 15, from Coosada; 16, from Edgewood; and 17, from Chalk Bluff, are given in the table D.

In Bibb county the clay has been quarried very extensively at Bibbville and near Woodstock for making fire brick. For this purpose the material is carried to Bessemer by the Alabama Great Southern Railroad. No. 18, from Woodstock; and 19, from Bibbville, will represent the average quality of the clay from these beds, which are very extensive, both in thickness and in superficial distribution. The Mobile & Ohio crosses other extensive deposits in the southern part of the county, but no analyses are available.

The most important of the clay beds in Tuscaloosa county are traversed by the Mobile & Ohio Railroad and by the Alabama Great Southern.

Analysis 20, from Hull's; and analysis 21, from the Cribbs beds, are on the Alabama Great Southern; and 22 and 23 are from cuts of the Mobile & Ohio, a few miles west of the city of Tuscaloosa.

Many large beds are exposed along the Mobile & Ohio road in Pickens county also, but very few have been as yet investigated. No. 24 is from Roberts Mill, in this county.

In Lamar and Fayette counties the same conditions prevail as in Pickens and Tuscaloosa. Analysis 25 is of pottery clay from the Cribbs place, in Lamar; and No. 26 is of clay from Wiggins's, 4 miles west of Fayette; and 27 and 28 are clays from W. Doty's place, 14 miles west of that town, in Fayette county.

Marion is one of the banner counties of the State for fine clays, but it is touched by railroads only along its southern border and in the extreme northeastern corner. Although at present not available because inaccessible, the clays mentioned below are worth consideration: No. 29, from Glen Allen; No. 30, from Briggs Fredericks', in Sec. 8, T. 10, R. 13 W. This is from the great clay deposit which gives the name to Chalk Bluff and which underlies about two townships. No. 31 is from a locality about 16 miles southwest of Hamilton, the county seat.

No. 32 is from a locality near the Mississippi line, in section 20, T. 8, R. 15 W., in Franklin county, from land of Mr. Thomas Rollins.

Of the numerous fine clays of Colbert county analyses are given of two from Pegram station, on the Southern Railway, near the Mississippi State line. These are Nos. 33 and 34.

Table A.

Analyses of Lower Carboniferous Limestones.

Number.	1	2	3	4	5	6	7	8	9	10
	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct
Silica	0.50	1.73	0.77	1.14	1.02	1.40	0.68	0.81	0.82	2.16
Iron and aluminum oxide	1.45	.78	.35	.34	1.38	1.17	1.02	.89	.60	2.31
Calcium carb'te.	96.58	96.54	97.60	98.53	95.25	94.67	96.54	97.45	97.37	89.15
Magnesium carbt	2.58	......	......	......	1.73	2.26	1.26	.35	.75	4.20
Sulphur	......	......	......	......	......	......	......	......	.029	......

Number.	11	12	13	14	15	16	17	18	19	20
	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct
Silica	3.12	0.85	1.08	0.73	0.64	1.12	0.42	2.05	4.45	2.80
Iron and aluminum oxide	2.32	.65	.61	.65	.62	.90	.37	.76	3.30	.70
Calcium carb'te.	85.87	96.64	96.91	97.60	97.48	96.38	97.32	89.64	86.35	94.59
Magnesium carbt	4.20	1.36	.90	.52	.76	1.10	1.39	8.15	......	......
Sulphur	......	.024	.019	.018	......	......	.020	......	......	......

1. Average sample from Fossick quarry, near Rockwood, Franklin County. Government Arsenal, Watertown, N. Y., analyst.

2. Average sample from Blount Springs quarry—a compact limestone. Henry McCalley, analyst.

3. Average sample from Blount Springs quarry—a granular oolitic limestone. Henry McCalley, analyst.

4. Average sample upper 75 feet, Blount Springs quarry. J. L. Beeson, analyst.

5-9. Average sample Blount Springs quarry. J. R. Harris, analyst.

10, 11. From Worthington quarry, near Trussville, Jefferson county. C. A. Meissner, analyst.

12-17. From Vanns, near Trussville. J. R. Harris, analyst.

18. Average of about 150 feet thickness of rock used for flux. Compton quarry, Blount county. J. L. Beeson, analyst.

19, 20. Stockhouse sample, Compton quarry. Wm. B. Phillips, analyst.

Table B.

Analyses of Trenton Limestones.

Number.	1	2	3	4	5	6	7	8	9	10
	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct
Silica	4.48	5.70	2.43	3.65	3.29	3.82	0.39	0.15	0.78	1.00
Iron and aluminum oxides	1.22	1.87	3.30	.91	1.49	1.96	.13	Tr	.35	.30
Calcium carb'te.	88.85	91.16	89.88	92.38	92.61	90.44	99.11	99.16	97.52	97.00
Magnesium carbt	3.52	......	......	......	......	......	.75	.75	1.27	Tr
Sulphur	......	......	......	......	......	......	......	......	......	Tr
Water, organic matter and loss	......	......	......	......	......	......	......	......	......	......

Number.	11	12	13	14	15	16	17	18	19	20
	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct
Silica	0.43	0.58	0.38	0.34	0.39	0.98	2.50	2.09	1.08	2.25
Iron and aluminum oxides	.42	.25	.47	.46	.37	.52	1.40	1.01	.63	.68
Calcium carb'te.	98.49	95.78	98.35	96.53	94.27	96.92	96.70	93.77	98.91	95.40
Magnesium carbt	.16	2.89	.30	2.17	4.47	1.08	......	2.48	.58	.94
Sulphur	......	......	......	......	......	......	......	......	......	......
Water, organic matter and loss	......	......	......	......	......	......	......	......	......	......

1. Average of several carloads flux rock from quarry at Vance, Tuscaloosa county, of Central Iron Company at Tuscaloosa. H. Buel, analyst.

2. Gate City quarry, Jefferson county. Average sample from the crusher. Henry McCalley, analyst.

3-6. Gate City quarry. J. W. Miller, analyst.

7, 8. Longview quarries, Shelby county. Used in lime burning. Report of Alabama State Geologist, 1875.

9. Jones quarry, near Longview. Report of Alabama State Geoligist, 1875

10. Rock Spring quarry, Etowah county. Used in lime burning and for flux. Wm. B. Phillips, analyst.

11-16. Rock from Calcis quarry, St. Clair county. J. R. Harris, analyst.

17-20. Shelby quarry, Shelby county. Used for flux in Shelby furnaces. Report of Alabama State Geologist, 1875.

Table C.

Analyses of Crystalline Marbles.

Number.	1	2	3	4	5	6	7
	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct
Silica	Tr	2.70	2.95	4.65	2.80	1.35	0.28
Iron and aluminum oxides.........	......	.40	1.15	.75	.48	.30	.28
Calcium carbnate	99.47	90.80	95.25	94.40	95.60	97.60	99.19
Magnesium carbonate	.38	Tr	.62	.41	.66	Tr	.14

1. Herd's upper quarry, Talladega county. Tuomey's Second Report.
2. Heard's quarry, sec. 16, T. 21, R. 4 E., Talladega county. Wm. B. Phillips, analyst.
3. Taylor's mill, Talladega county, white marble. Wm. C. Stubbs, analyst.
4. Taylor's mill, Talladega county, blue marble. Wm. C. Stubbs, analyst.
5. Taylor's mill, Talladega county. A. F. Brainerd, analyst.
6. Nix quarry, sec. 36, T. 20, R. 4 E., Talladega county, white marble. Wm. B. Phillips, analyst.
7. Gannt's quarry, sec. 2, T. 22, R. 3 E., Talladega county, white marble. A. F. Brainerd, analyst.

Table D.

Analyses of Clays—Paleozoic and Lower Cretaceous.

Number.	1	2	3	4	5	6	7	8	9
	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct
Silica	61.55	57.80	57.22	58.50	79.80	82.04	66.25	82.11	60.50
Alumina	20.25	25.00	24.72	18.28	11.75	12.17	22.90	11.41	26.55
Ferric oxide	7.23	4.00	7.14	10.22	1.75	Tr	1.60	1.40	.30
Lime	Tr	2.10	.49	1.19	.75	Tr	Tr	Tr	.90
Magnesia	.99	.80	1.88	1.40	Tr	.33	Tr	.66	.65
Alkalies	1.25	1.80	.40	.70	1.50	.60	.75	1.80	2.70
Ignition	6.19	7.50	7.09		4.11	4.33	9.05	4.00	7.90
	98.63	99.00	98.93	......	99.16	99.47	100.55	101.38	99.50

Number.	10	11	12	13	14	15	16	17	18
	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct
Silica	72.20	57.00	67.95	61.50	84.21	66.61	62.60	60.38	65.82
Alumina	22.04	17.80	20.15	26.20	9.75	21.04	26.98	20.21	24.58
Ferric oxide	.16	5.60	1.00	2.10	.69	2.88	.72	6.16	1.25
Lime	.50	2.10	1.00	.50	.70	.40	.40	.09	......
Magnesia	.40	1.20	Tr	.43	.14	.58	.36	.72	Tr
Alkalies	.60	6.00	1.87	.70	....	.70	.65	1.80	.60
Ignition	5.80	9.45	8.00	7.29	4.10	7.00	9.30	10.21	8.16
	101.70	99.15	99.97	98.72	99.59	99.21	101.01	99.57	100.41

Number.	19	20	21	22	23	24	25	26	27
	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct
Silica	74.25	61.25	65.35	60.03	58.13	68.23	60.90	63.27	67.10
Alumia	17.25	25.60	21.30	24.66	24.68	20.35	18.98	19.68	19.37
Ferric oxide	1.19	2.10	2.72	3.69	3.85	3.20	7.68	3.52	2.88
Lime	.40	.25	.60	.13	.15	.34	Tr	1.30	Tr
Magnesia	Tr	.82	.86	.38	.32	Tr	Tr	Tr	.73
Alkalies	.52	1.35	Tr	Tr	1.78	.74	Tr	1.20	.67
Ignition	6.30	8.10	8.79	11.34	11.78	7.16	13.36	9.80	7.79
	99.39	99.47	99.62	100.23	100.51	100.02	100.92	98.77	98.54

Number.	28	29	30	31	32	33	34		
	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct	Pr ct		
Silica	65.58	68.10	65.49	70.00	67.50	66.45	64.90		
Alumina	19.23	21.89	24.84	21.31	19.84	18.53	25.25		
Ferric oxide	4.48	2.01	Tr	2.88	6.15	2.40	Tr		
Lime	Tr	.80	1.26	.20	.12	1.50	Tr		
Magnesia	Tr	.28	Tr	Tr	.10	1.25	Tr		
Alkalies	....	.40	Tr	Tr	....	Tr	....		
Ignition	6.90	5.75	7.80	6.85	7.65	9.46	8.90		
	96.19	99.23	99.39	101.24	101.36	99.59	99.05		

Coal Measures..	1. Dark yellow shale from Coal Measures, W. H. Graves, near Birmingham, Jefferson county. 2. Light gray shale from same locality. 3. Shale from Coaldale, Jefferson county. Analysis by F. W. Miller. 4. Shale over coal seam, Cedar Grove Coal Mines, near Vance, Tuscaloosa county.
Lower Carboniferous	5-7 Fire clay, near Valley Head, DeKalb county. 8. China clay, Eureka mines, DeKalb county.

Silurian and Cambrian.	9. China clay, Rock Run, Cherokee county (Dyke's ore bank.)
	10. Fire clay, Rock Run, Cherokee county.
	11. Pottery clay, Rock Run, Cherokee county.
	12. China clay, J. R. Hughes, Gadsden, Etowah county.
	13. Stoneware clay, Blount county.
	14. Stevens. Fire clay, Oxanna, Calhoun county; probably too much free sand.
Lower Cretaceous (Tuscaloosa)	15. Stoneware clay, Coosada, Elmore county.
	16. Pottery clay, McLean's, near Edgewood, Elmore co.
	17. Stoneware clay, Chalk Bluff, Elmore county.
	18. Fire clay, Woodstock, Bibb county.
	19. Fore clay, Bibbville, Bibb county.
	20. Fire clay, Hulls Sta'n., A. G. So. R. R. Tuscaloosa co.
	21. Pottery clay, H. H. Cribbs, A. G. So. R. R., Tuscaloosa county.
	22. Pottery clay, J. C. Bean, M. & O. R. R., Tuscaloosa co.
	23. Fire clay, J. C. Bean, M. & O. R. R., Tuscaloosa co.
	24. Stoneware clay, Roberts' Mill, Pickens county.
	25. Pottery clay, Cribbs' place, Lamar county.
	26. Stoneware clay, H. Wiggins, Fayette county.
	27-28. Pottery clay, W. Doty, Fayette county.
	29. Blue clay, R. R. cut, near Glen Allen, Marion county.
	30. China clay, Briggs Frederick, Marion county.
	31. Pottery clay, 10 miles S. W. Hamilton, Marion co.
	32. Pottery clay, Thos. Rollins, Franklin county.
	33. Pottery clay, J. W. Williams, Pegram, Colbert co.
	34. China clay, Pegram, Colbert county.

CHAPTER II.

THE PORTLAND CEMENT MATERIALS OF CENTRAL AND SOUTHERN ALABAMA.

The raw materials suitable for the manufacture of Portland cement, which occur in Central and Southern Alabama, are argillaceous limestones, purer limestones, and clays.

The limestones valuable as cement materials occur mainly at two horizons, viz., in the Selma chalk or Rotten limestone of the Cretaceous, and in the St. Stephens formation of the Tertiary. The clays available are residual clays from the decomposition of the two limestone formations above mentioned, the stratified clays of the Grand Gulf formation, and alluvial clays occurring in the river and creek bottoms. It is further possible that later investigation may show that some of the other stratified clays of the Tertiary formations are suitable, and this is especially likely to be the case with the clays of the lowermost Cretaceous or Tuscaloosa formation.

THE SELMA CHALK OR ROTTEN LIMESTONE.

Geological horizon.—The Cretaceous system in Alabama is susceptible of classification into four divisions, which are, in ascending order,

1, the Tuscaloosa, a formation of fresh-water origin, made up in the main of sands and clays in many alterations. In places the clays occur in deposits of sufficient size and of such a degree of purity as to make them of commercial value.

2, the Eutaw, which is of marine origin and composed of sands and clays more or less calcareous, but nowhere showing beds of limestone properly so called.

3, the Selma chalk, which is of marine origin, and is composed, in part at least, of the microscopic shells of Foraminifera. This formation, throughout the western part of the belt covered by it in Alabama, is about 1,000 feet in thickness, and is made up of beds of chalky and more or less argillaceous limestone. In a general way it may be said that the lower and upper thirds of the formation contain 25 per cent. and upward of clayey matters mixed with the calcareous material, while the middle third will hold less than 25 per cent. of these clayey impurities.

4, the Ripley. This, like the preceding, is a marine formation, in which, generally, the calcareous constituents predominate, but in places it contains sandy and clayey beds.

From this summary it will be seen that the Selma chalk is the one of Cretaceous formations in Alabama which offers limestone in such quantity and of such composition as to be fit for Portland cement material.

General description.—As has been stated above, the Selma chalk is a calcareous formation throughout its entire thickness of about 1,000 feet. The rock, however, varies in composition between somewhat wide limits, and taking account of the composition we may readily distinguish three divisions of it. The rock of the upper or Portland division is highly argillaceous, holding from 25 per cent. and upward of clayey matters; portions of it are composed of calcareous clays or marls rather than limestone, and in these beds are found great numbers of fossils, mainly oysters. Along Tombigbee River these beds make the bluffs from Pace's Landing down nearly to Moscow, and on the Alabama they form the banks of the river from Elm Bluff down to Old Lexington Landing. The strata, as exhibited in these bluffs, consist of dark-colored, fossiliferous, calcareous clays, alternating with lighter-colored and somewhat more indurated ledges of purer, less argillaceous rock. At Elm Bluff, which is about 125 feet high, the upper half of the bluff is of this character. The lower half of the bluff is composed of rock more uniform in composition and freer from clay, and is the top of the middle part of the Selma formation (the Demopolis division), which is made up of limestone of more uniform character, containing, generally, less than 25 per cent. of clayey material.

In this middle or Demopolis division of the Selma formation the fossils are rarer than in either of the others, oysters and anomias being the most common forms. This variety of the rock forms the bluffs along Alabama River from Elm Bluff up to King's Landing. It is seen in its most typical exposure at White Bluff, where it is at least 200 feet in thickness, and makes on the right bank of the river an almost perpendicular bluff. On Tombigbee River it extends from near Barton's Bluff past Demopolis up to Arcola and Hatch's Bluff. Its lowermost beds, a compact limestone of great purity, form the upper parts of Barton's and Hatch's Bluffs. On Little Tombigbee River the same rock makes the celebrated bluffs at Bluffport and at Jones Bluff (Epes), beyond which for several miles it is shown along the stream.

Judging from the width of its outcrop, this division of the Rotten limestone must be about 300 feet in thickness. It underlies the most fertile and typical "prairie" lands of the South. At intervals throughout this region the limestone rock appears at the surface in what are known as "bald prairies," so named from the circumstance that on these spots there is no tree growth. The disintegration and leaching out of the limestone leaves a residue of yellowish clay, which accumulates sometimes to a thickness of several feet in low places. This clay is used at the Demopolis plant in the manufacture of cement, and in most localities where suitable limestone is found the clay is present in sufficient quantity to supply the needs of the cement manufacturer.

At the base of this middle or Demopolis division occurs a bed consisting of several ledges of compact, hard, pure limestone, which weathers into curious shapes, and has received the names horse-bone rock and bored rock. This bed, as above mentioned, appears at the top of Hatch's Bluff; also at Arcola Bluff, and between Demopolis and Epes, at Jordan's Ferry, and other places. Where it outcrops across the country it makes a ridge easily followed and characterized by the presence on the surface of loose fragments of the limestone.

The lower part of the formation (the Selma division), like the upper, is composed of clayey limestone, in many places being rather a calcareous clay. The color is dark gray to bluish, and in most exposures there is a striping due to bands of light-colored, purer limestone alternating with the prevailing quality. Along Alabama River the strata of this division are seen in the bluffs from King's Landing up to Selma and beyond. On the Warrior River they are seen in the bluffs at Arcola, Hatch's, Millwood, and Erie, occupying in the last-named locality the upper part only of the bluff. On the Tombigbee, the bluffs at Gainesville, at Roe's, and Kirkpatrick's are formed mainly of

other considerations than the quality of the rock. Chief among these will be the facilities for transportation, cheapness of fuel, cost of labor and abundance of it at command.

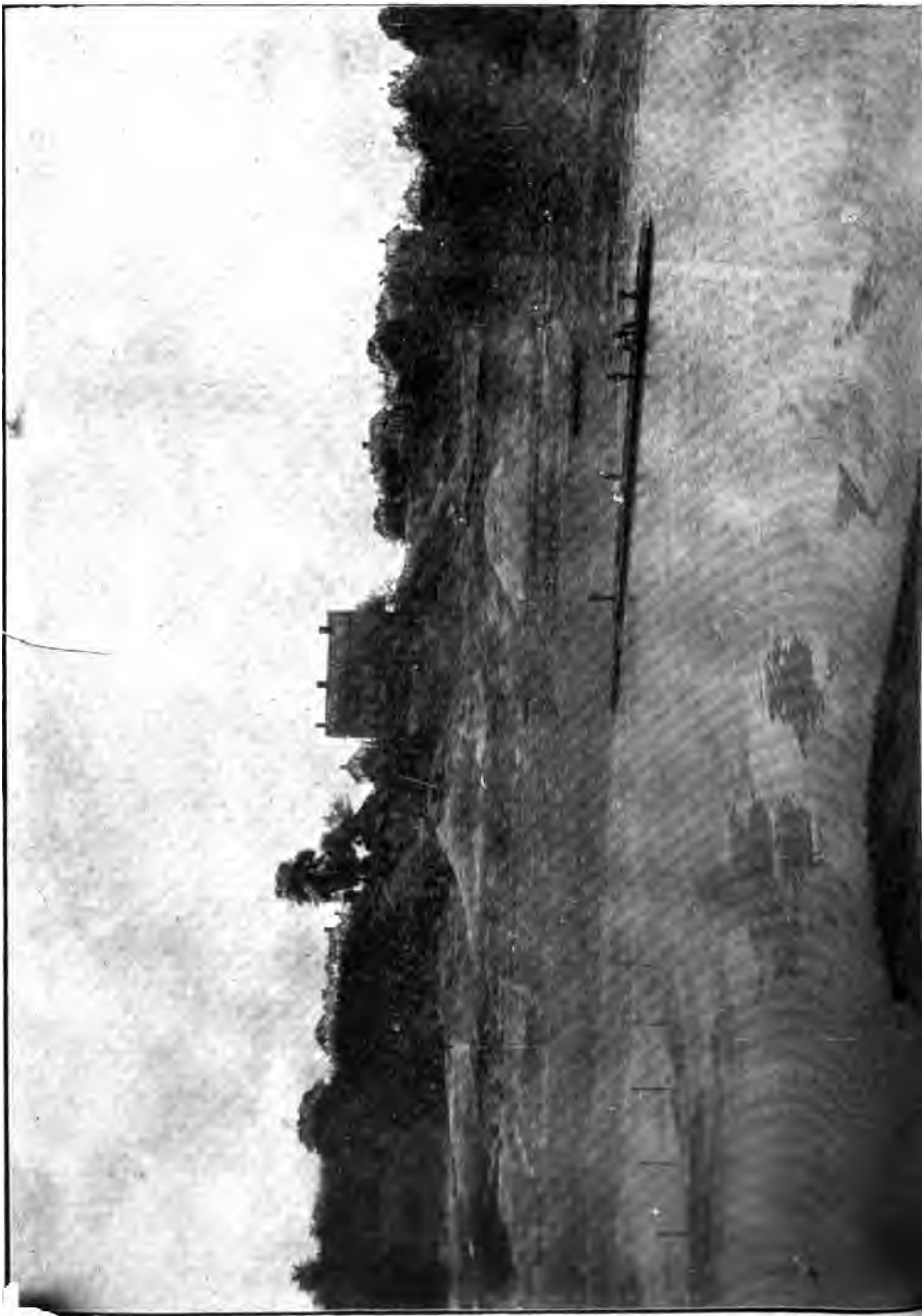
Examinations have consequently been confined to those localities which appear to be most favorably situated in these respects, and especially to those localities which are on navigable streams or on north-south railroad lines, or on both.

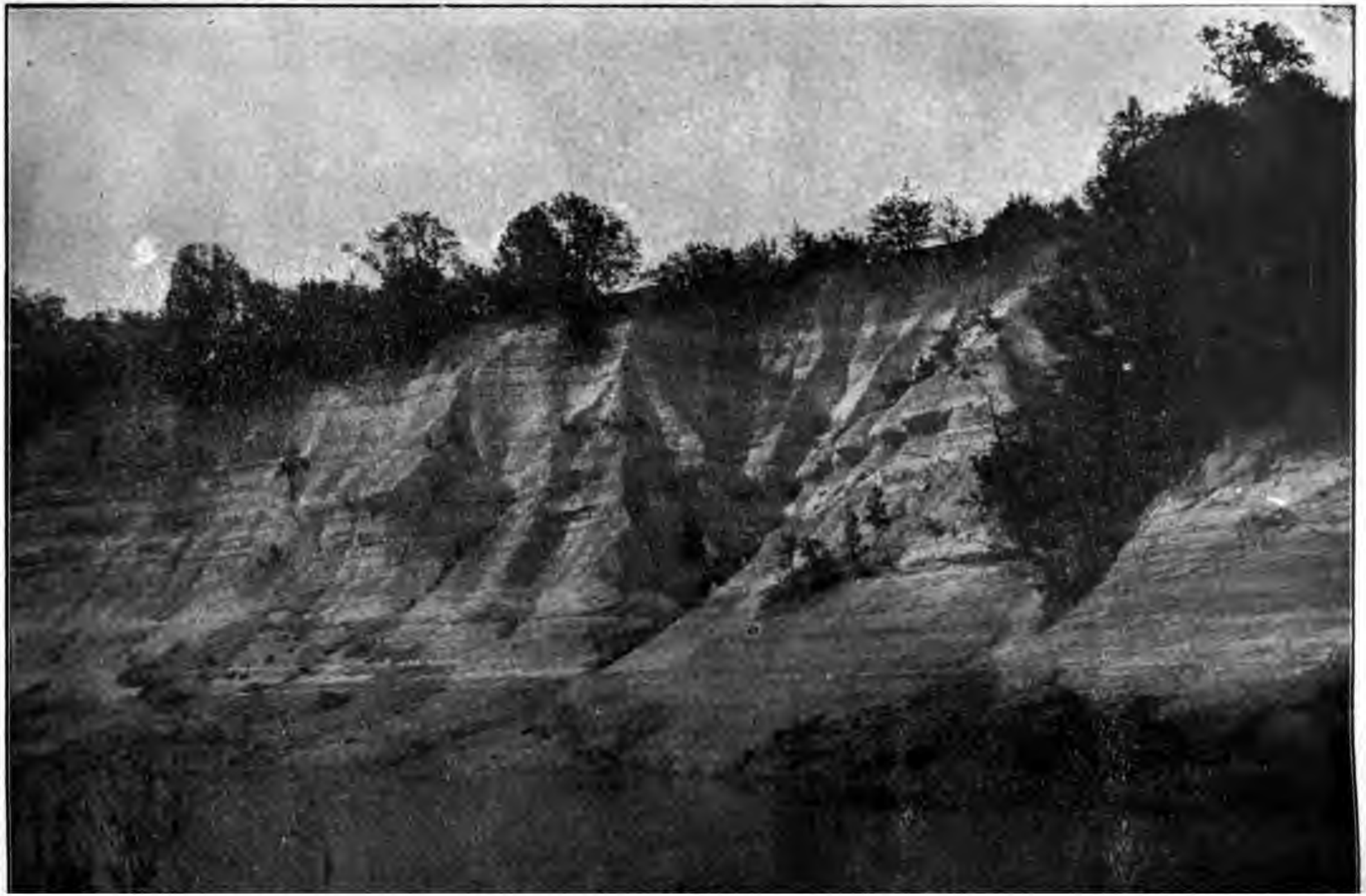
The first place considered on Tombigbee River is Gainesville, where the limestone appears on the river bluff in a thickness of 30 to 40 feet, beneath a heavy covering of Lafayette sands and pebbles. (Plate III.) A short distance inland from the river, however, the rock appears at the surface, and may be quarried without difficulty. Specimens have been taken from the different parts of the bluff near the ferry, which will show the composition of the limestone here (see analyses 1, 2, 3, and 4, Table E). Other specimens are from the Roberts place, 3 miles east of Gainesville—one of which was taken from the top of a 30-foot bluff; others from the surface 1 mile and 5 miles from the river (analyses 5 and 6.)

At Jones' Bluff, on the Tombigbee, near Epes station, on the Alabama Great Southern Railroad, the white limestone of remarkably uniform composition shows along the river bank for a distance of a mile or so, with an average height of perhaps 60 feet. (Plate IV.) Here the bare rock forms the surface, so that there would be no overburden to be removed in quarrying. The railroad crosses the river at this locality, which thus has the advantage of both rail and water transportation. From the lower end of this exposure down to Bluffport the white rock is seen at many points, e. g., below Lees Island, Hillman's (Plate V), Martin's Ferry, Braggs, etc. It generally has a capping of 15 to 20 feet of red loam and other loose materials.

Specimens have been analyzed from Epes and Hillmans (analyses 7, 8 and 9, Table E.)

At Bluffport (Plate VI) the white rock in places forms a bluff 100 feet or more in height along the right bank of the river for a distance of a mile or more. This is the counterpart of Jones' bluff, above mentioned, and the character of the material is shown by analysis No. 10. As at Epes. the rock extends up to the surface, so that the quarrying would be attended with little or no difficulty. Below the Bluffport bluffs the easterly course of the river brings it into the territory of the lower





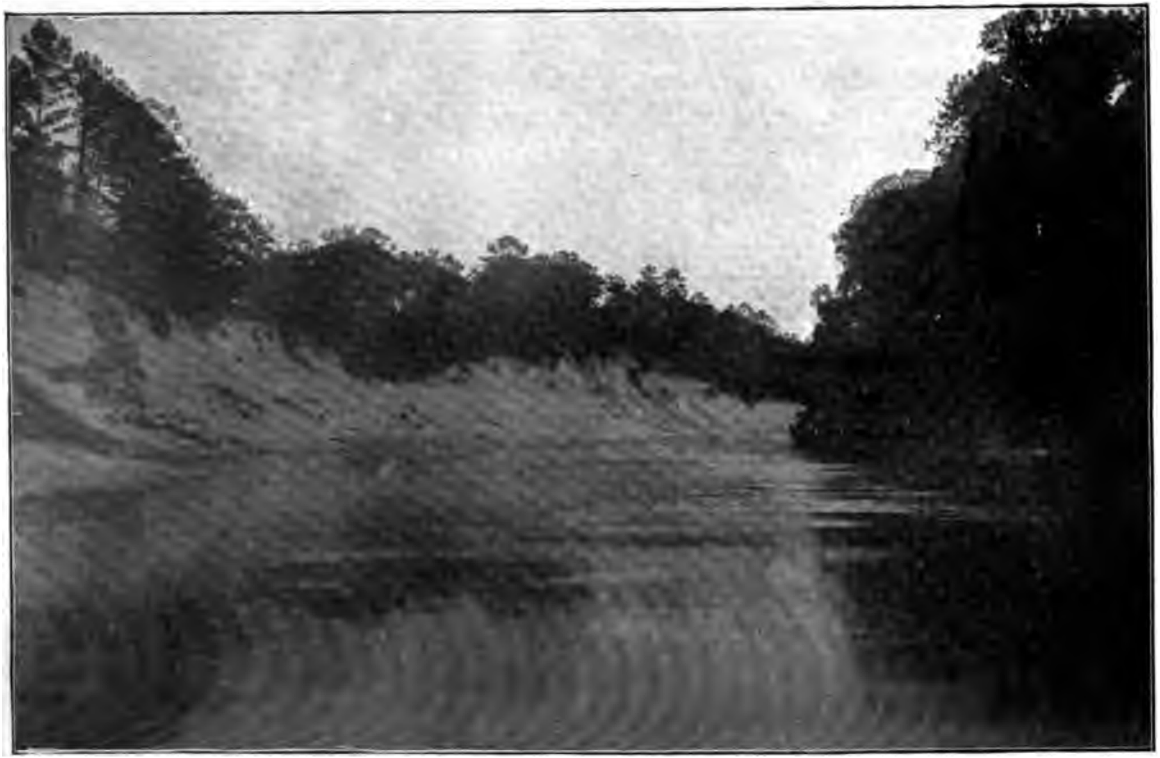


Plate VIII.—Roe's Bluff, Tombigbee River.

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strata of the formation, and we do not see the white rock again below Jordan's Ferry, (Plate VII) except in thin patches at tops of some of the bluffs. The character of the material of these lower beds may be seen from the analyses of specimens taken from Jordans and Belmont and Roe's bluff, Nos. 11, 12, 13, and 14. The two specimens from the last-named locality represent the composition of the prevailing dark-colored argillaceous rock and of the lighter-colored ledges. (Plate VIII.)

At Demopolis there is an important occurrence of the white rock extending along the left bank from a mile above the landing to about 2 miles below, with an average height perhaps of 40 or 50 feet. (Plates IX and X.) The rock is remarkably uniform in appearance and probably in composition (analysis 17.) At McDowell's the main bluff is on the right bank and the rock is of great purity, as shown by analysis 16. The exposures continue down to Pace's Landing, 9 miles below Demopolis, and beyond this the bluffs are much darker in color and striped with lighter bands, characteristic of the strata of the upper part of the formation. Thence down nearly to Moscow occur the exposures of these upper beds.

Above Demopolis at Arcola and Hatch's bluff the bluish clayey limestones of the Selma division are seen in force, with the lowermost ledges of the Demopolis division—the horse-bone rock—capping them. Two analyses of these varieties at Hatches will show well the contrast in their chemical composition (analyses 19 and 20. (Plate XI.)

From Demopolis eastward the line of the Southern Railway is located on the outcrop of this white rock, at least as far as Massillon, where it passes into the territory of the lower Selma division. Two miles from Demopolis on this road is the cement manufacturing plant of the Alabama Portland Cement Company, with six kilns in place. The quarry is on the opposite side of the railroad track from the kilns, but only a few hundred feet distant. (This plant with quarry in the foreground is shown in Plate XII.) The clay used is the residual clay from the decomposition of the limestone, and is obtained from the river bank a few yards away. The composition of the rock and of the clay used in the manufacture is shown by analyses 15, 18, and 31, Table E, and 1, Table G. A specimen taken from Knoxwood station, between the cement works and Demopolis station, shows similar composition. The analyses below given (10, 11, 12 of Table G) show the chemical character of the cement manufactured at Demopolis.

At Van Dorn station the white rock outcrops in the fields over considerable territory, (Plate XIII), and just east of the station there is a deep cut through it. Analyses from about Van Dorn show sufficiently well the character of the material at these points (analyses 21 and 22 of Table E.)

About Uniontown the bare rock is exposed at numerous points, and the advantages of this place for the location of manufacturing plants seem to be very great. Specimens have been taken from the Bradfield and Shields places, west of the town, and from the Pitts place east, and from a point south of the town along the McKinley road. Other specimens have come from plantations near the road for several miles eastward and the analyses are appended (analyses 23, 24, 25, 26, 27 and [illegible]

The composition of the residual clay overlying the limestone at the Pitts place is shown in analysis No. 2 of Table G, and that of a similar clay from the "Graveyard Hill" on the Morgan place, by analysis No. 3 of same table.

South of Massillon, near the crossing of the Southern and Louisville and Nashville railroads, in the vicinity of Martin's station, the white rock shows in numerous exposures through the fields, making a country somewhat similar to that about Uniontown. At many points the rock has no overburden, and is admirably adapted to cheap quarrying. On the banks of Bogue Chitto Creek, near Martin's station, on the Milhous place, the rock is exposed in a bluff with a bed of plastic clay overlying, but here it is below a considerable thickness of red loam and sands of the Lafayette formation. The character of the rock at Milhous station, west of Martin's, may be seen from the analysis No. 29, Table E.

The same rocks make the great bluff of White Bluff, on Alabama River, (Plate XIV.) Specimens were selected from this bluff at two points—one about halfway down the bluff, the other twenty feet lower. Generally there is a capping of the red loam and sands of the Lafayette over the limestone, but near the upper end of the bluff the white rock extends to the summit, where it has a capping of plastic clay only. The charaster of the limestone from this locality is shown in analysis 30, Table E, and that of the overlying residual clay in analysis 4 of Table G.

At Elm Bluff, as has already been shown, the upper and middle divisions of the formation are in contact. (Plate XV.)

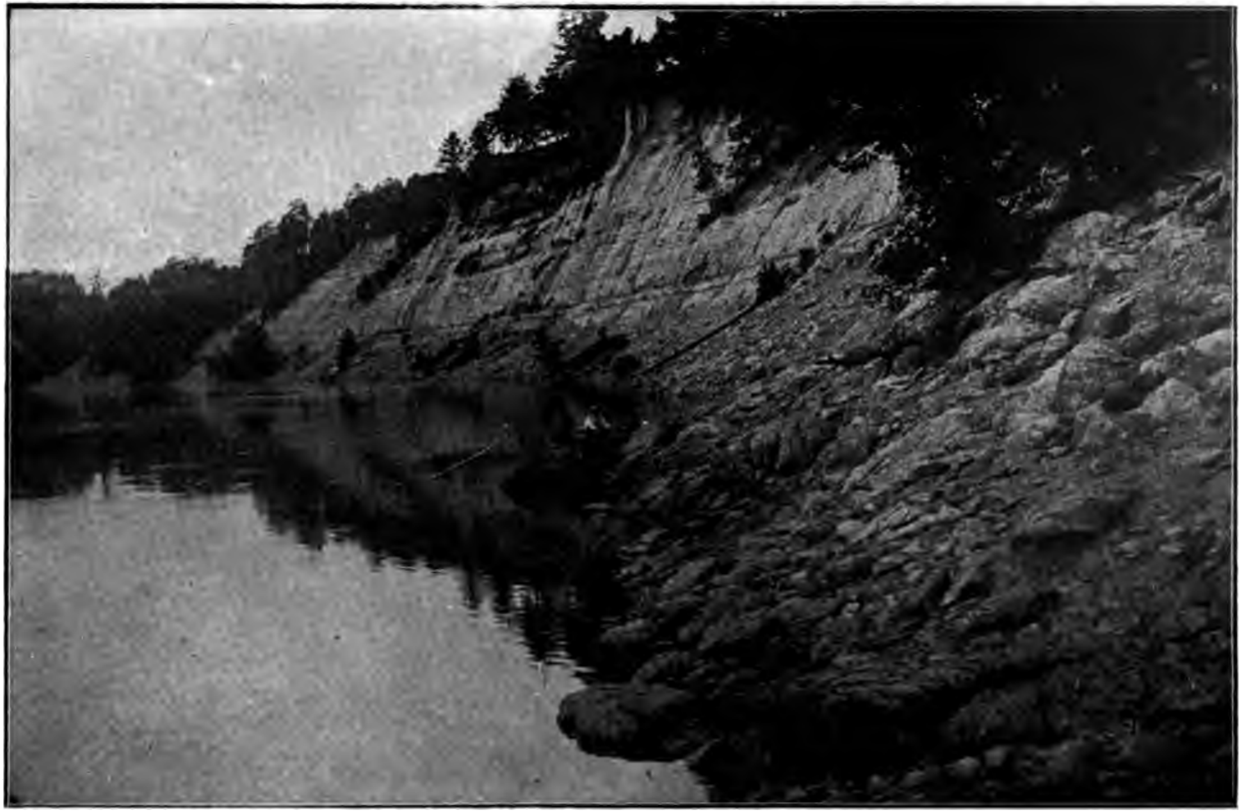


Plate XIV.—White Bluff, Alabama River.

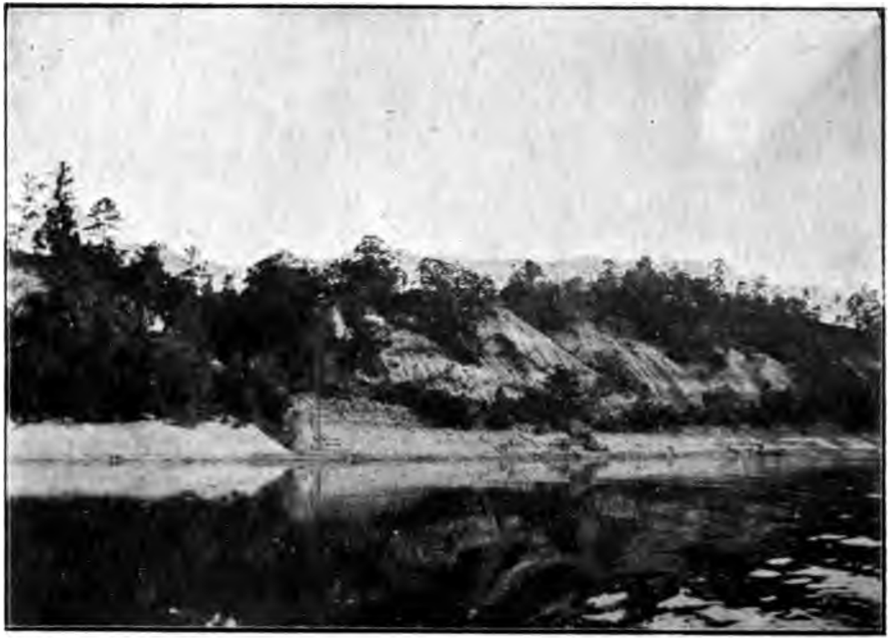


Plate XV.—Elm Bluff, Alabama River.

At King's Bluff the middle and lower parts of the formation are in contact. At the other bluffs of the river between King's Landing and Selma the rock of the lower division is exhibited. No. 32 (Table E) is of the rock at the steamboat landing in Selma; No. 33 of rock occurring near Selma; No. 34 from Cahaba; and No. 35 from Benton.

These analyses show that the rock of this division is in general too clayey for the best cement rock, but it might be mixed with the purer limestone of Uniontown, or Demopolis in making up a cement mixture.

To summarize: From Demopolis eastward along the line of the Southern Railway, by Van Dorn, Gallion, Uniontown, Massillon, and thence by Martins and Milhous stations to White Bluff, the white or Demopolis type of rock appears at the surface in clean exposures at almost innumerable points, either immediately on the railroad or at very short distance from it. So far as the quality, quantity, and accessibility of the limestone rock are concerned, manufactories of cement might be located almost anywhere in this territory. From Demopolis westward the same conditions prevail up the river to Epes, and thence to Gainesville, beyond which point the white rock is to the west of the river at greater or less distance.

East of Alabama River the outcrop of the cement rock is crossed by the Louisville and Nashville Railroad (Repton branch), as before stated, between Berlin and Pleasant Hill stations. At Benton, on Alabama River, and on the railroad, the limestone has the composition shown by analysis 35.

On the Montgomery and Selma road, at the crossing of Pintlala Creek near Manack station, the limestone is exposed in the creek banks and in the open fields, often with little or no overburden. In Table E are given analyses of a specimen from the fields along the wagon road (No. 36), and from the creek bank (No. 37.)

On the main branch of the Louisville and Nashville Railroad the white rock shows between the city and McGhees switch, and an analysis of a specimen from McGhees is given (No. 38.) Somewhat similar, but rather better, is the limestone from H. A. Jones, 8 miles south of Montgomery, shown in analysis No. 39.

Examinations have not been carried beyond Montgomery, but it is known that the white prairie rock is crossed by the Central of Georgia Railroad between Matthews and Fitzpatrick stations, and there seems to be no doubt that along this stretch of the road suitable rock will be found convenient to the line.

Table E.

Analyses of Crateceous Limestones.

Locality.	Silica.	Iron and aluminum oxides.	Calcium carbonate.	Magnesium carbonate.	Sulphuric anhydride.	Total sulphur.	Water and organic matter.
1 Gainesville Bluff, Tombigbee river, 5 feet from top of bluff; R. S. Hodges, analyst	18.46	16.04	56.71	1.69	1.32	.....	5.78
2 Gainesville Bluff Tombigbee river, lower part of bluff; R. H. Hodges, analyst	14.50	11.64	67.67	2.26	1.97	.....	1.96
3 Gainesville limestone; F. P. Dewey, analyst	18.42	10.79	65.21	1.57	.30	0.83	.....
4 Gainesville limestone; A. W. Dow, analyst	27.25	15.96	54.00	1.11	.44	1.23	.....
5 Robert's place, near Gainesville, top of bluff; R. S. Hodges	12.10	10.70	75.57	1.24	.69	.....	1.70
6 Robert's place near Gainesville, 5 feet above water; R. S. Hodges	14.28	11.80	69.75	1.50	1.02	.....	1.65
7 Jones Bluff, at Epes; R. S. Hodges	4.78	6.42	86.28	1.02	......	.....	1.30
8 Jones Bluff, at Epes; Dr. Mallett	3.23	3.96	80.48	.53	......	.....	2.22
9 Hillmans Bluff, below Epes; R. S. Hodges	10.08	9.47	77.43	1.30	......	.....	1.99
10 Bluffport ferry, Tombigbee river; R. S. Hodges	8.10	5.40	85.10	1.25	......	.....	.....
11 Jordans ferry Tombigbee river; R. S. Hodges	......	......	67.28	1.87	......	.....	1.53
12 Belmont Bluff, Tombigbee river; R. S. Hodges	21.00	15.60	55.84	2.12	......	.....	5.44
13 Roes Bluff, Tombigbee river, main part of bluff; R. S. Hodges	20.40	15.76	55.82	2.10	......	.....	5.92
14 Roes Bluff, Tombigbee river, light-colored ledges R. S. Hodges	9.68	8.70	78.52	1.02	......	.....	2.08
15 Demopolis limestone F. P. Dewey; U. S. Mint, analyst	13.32	7.74	73.94	1.40	.27	.64	.....
16 McDowells Bluff, below Demopolis; R. S. Hodges	3.82	3.86	90.40	1.15	......	.....	.77
17 Demopolis limestone; Dr. J. W. Mallett, analyst	12.13	7.45	77.69	.72	......	.....	2.49
18 Material used in Demopolis Cemen Wks; R. S. Hodges, analyst	7.64	7.62	80.71	1.05	1.62	.....	1.36
19 Hatch's Bluff Warrior river above Demopolis, main part of bluff; R. S. Hodges	25.90	19.41	44.78	2.68	......	.....	7.20
20 Hatch's Bluff, Warrior river above Demopolis; ledges at top of bluff; R. S. Hodges	1.78	2.34	93.52	1.38	......	.....	.98

Analyses of Crateceous Limestones.—Continued.

	Locality.	Silica.	Iron and aluminum oxides.	Calcium carbonate.	Magnesium carbonate.	Sulphuric anhydride.	Total sulphur.	Water and organic matter.
21	At VanDorn station, from roadside R. S. Hodges	8.90	8.26	80.47	1.30	......	.....	1.07
22	At VanDorn station, railroad cut east of station R. S. Hodges.....	9.80	7.85	78.77	1.04	......	.....	2.54
23	Uniontown, P. H. Pitt's Home place; R. S. Hodges	10.86	8.40	75.35	1.35	......	.....	4.04
24	Uniontown, P. H. Pitts, Houston place; R. S. Hodges	13.58	9.20	72.21	1.98	......	.....	3.03
25	Uniontown, P H. Pitts, Rural Hill place; R. S. Hodges	12.10	9.80	74.52	1.17	......	.....	2.41
26	Uniontown, 1 mile south on McKinley road; R. S. Hodges........	7.56	7.18	83.45	1.53	......	.....	.....
27	Uniontown, Bradfield place; R. S. Hodges	17.77	9.24	65.96	1.52	......	.....	5.51
28	Uniontown, Shields place; R. S. Hodges	19.62	11.71	62.81	2.04	......	.....	2.49
29	R. R. cut, Milhous station, So. Ry. Dallas county R. S. Hodges......	10.50	7.24	80.10	.98	......	.....	1.18
30	White Bluff, Alabama river, lower part of bluff R. S. Hodges........	17.44	11.48	64.35	1.61	......	.....	5.22
31	Limestone used in cement works, Demopolis; analysis furnished by T. G. Cairns	9.88	6.20	77.12	1.08	......	.....	5.73
32	Limestone from bluff at steamboat landing, Selma; F. W. Miller, analyst	16.11	11.22	65.08	2.42	1.40	.....	3.37
33	Near Selma, white rock; O. M. Cawthon, R. S. Hodges............	18.66	13.42	64.10	2.58	.08	.....	1.16
34	Limestone from Cahaba, Alabama river; Dr. Mallet....................	19.64	9.40	65.81	.79	......	.....	3.58
35	Limestone from Benton, Alabama river; Dr. W. B. Phillips...........	19.74	11.67	54.83	5.14	.85	.....	4.96
36	Limestone from Manack station, Lowndes county; R. S. Hodges...	13.50	11.46	67.16	1.08	1.01	.....	5.79
37	Limestone, Manack station; Dr. B. B. Ross, analyst	13.20	9.00	74.26	1.46	......	.....	.....
38	Limestone, McGhee's Switch, Montgomery co.; R. S. Hodges...	21.98	14.78	54.67	1.39	.11	.....	7.07
39	Limestone, H. A. Jones, 8 miles S. of Montgomery; R. S. Hodges....	14.90	14.34	63.28	1.47	......	.....	6.01

THE ST. STEPHENS LIMESTONE.

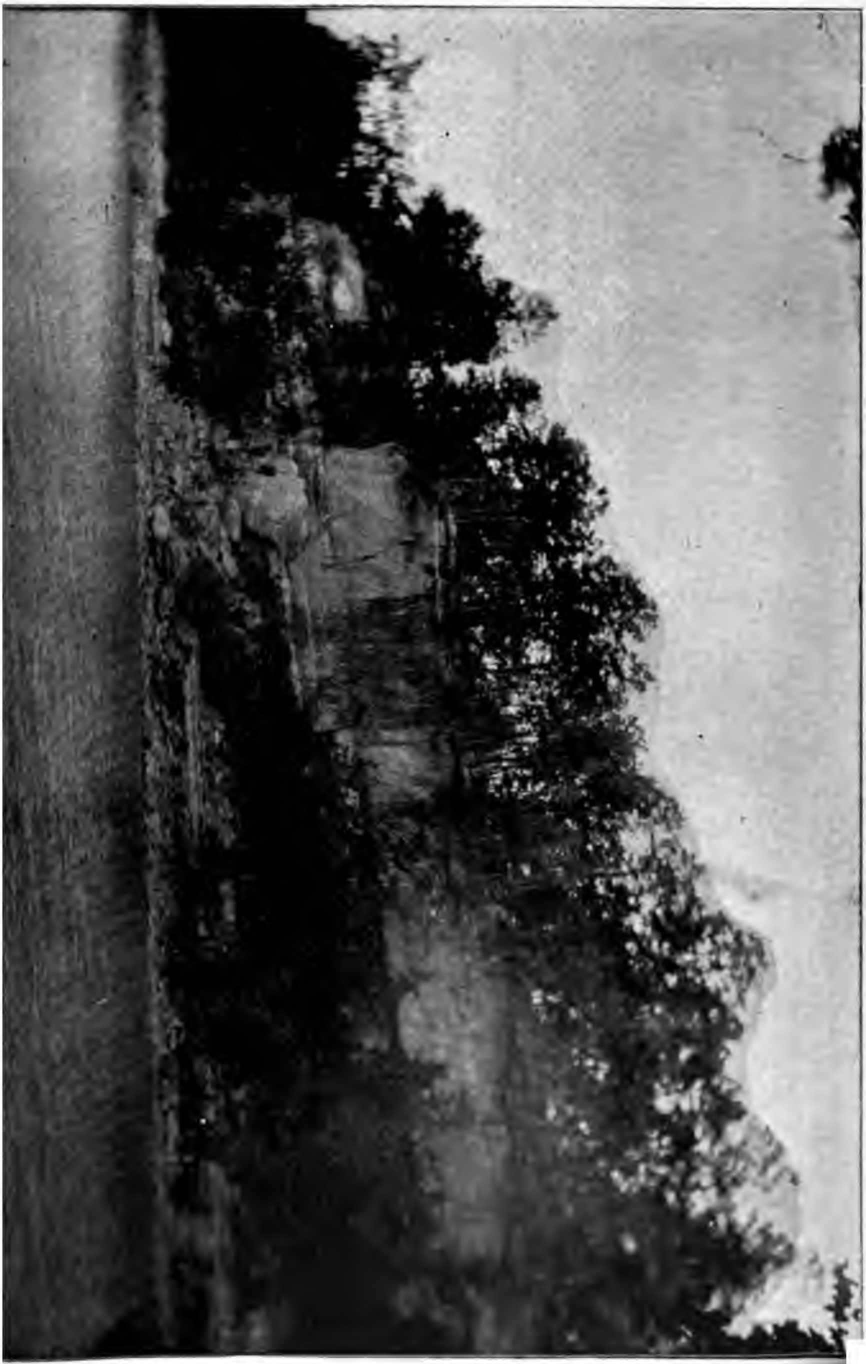
General Description.—The St. Stephens or White limestone formation of the Alabama Tertiary, which includes the uppermost of the Eocene strata, is in general equivalent to the Vicksburg limestone of the Mississippi geologists.

In Alabama it exhibits three rather well-defined phases, which in descending order are (1) the Upper or Salt Mountain division, observed at one locality only in Clarke county; (2) the Middle or St. Stephens division, and (3) the Lower or Jackson division. Of these it is only the middle division with which we are here concerned, since the first is, so far as known, restricted to one locality, and the third is seldom exposed along Alabama rivers and railroads.

The following section of the St. Stephens Bluff, Tombigbee River, (Plate VI), will give an idea of the strata of this division:

Section of St. Stephens Bluff.

	Feet.
1. Red residual clay	1 to 5
2. Highly fossiliferous limestone holding mainly oysters, and full of holes, due to unequal weathering	10 to 12
3. Orbitoidal limestone (chimney rock), a soft, nearly uniform porous limestone, making smooth perpendicular face of the bluff except where bands of harder limestone of very nearly similar composition alternate with the softer rock. Both varieties hold great numbers of the circular shells of *Orbitoides mantelli*. These harder ledges are nearly pure carbonate of lime, take a good polish, and are often burned for lime..............	60
4. Immediately below 3. for 5 or 6 feet, the strata were not visible, being hidden by the rock falling from above, but the space seems to be occupied by a bluish clay. Then follows a soft rock somewhat of same consistency as No. 3 above, but containing a good deal of green sand. The fossils are mostly oysters and *Plagiostoma dumosa*. This bed is in places rather indurated superficially, and forms projecting ledges................	10 to 15



5. Bluish clayey marl with much green sand, containing the same fossils as No. 4. It washes or caves out from under No. 4, which overhangs it.................... 4 to 5

6. Massive joint clay, yellow on exposed surface, blue when freshly broken; no fossils observed. Extends below the water level to unknown depth; exposed .... 3 to 4

The rock of this formation, which seems to be the best suited for cement material, is the soft "chimney rock" or orbitoidal limestone of bed No. 3 above. This usually quarried for chimneys and other constructions by sawing it out and dressing it down with a plane into blocks of suitable size, which are then laid like brick.

The numerous analyses given below will show that this rock is a purer limestone than most of the material of the Selma chalk of the Cretaceous formation above considered. In cement making it will, in consequence, require a larger proportion of clay to be mixed with it, and the question of obtaining suitable clay in sufficient quantity and in close proximity becomes one of some importance. The residual clay left after decomposition and leaching of the limestone seems to be fairly well adapted to the purpose. Besides this residual clay some analyses have been made of the clays of the river and creek bottoms of the country near the limestone outcrops, and of the clays of the Grand Gulf formation, which very generally in this section overlies the limestone. Some analyses of the last named clays have been made from material occurring near St. Stephens, and near Manistee Junction on the Repton Branch of the Louisville and Nashville Railroad. At this last-named locality the clay is present in sufficient quantity to be of value if the composition is suitable.

Details of Localities.

St. Stephens.—The first locality to be considered is the bluff at St. Stephens, a section of which has been given, and it may be taken as a typical section of the formation everywhere. At St. Stephens the whole of the soft orbitiordal limestone or "chimney rock" might be used, as the composition is uniform throughout. The overlying harder limestone has almost the same composition, but it is less easily crushed and handled. It may be quarried here from the surface down, as it is covered only by a thin layer of residual clay. The characters of the limestone and of the clay from here are sufficiently well shown by the subjoined analyses (No. 1 of Table F, and 5 and 6, Table G.) The character of the clay of Grand Gulf formation near St. Stephens is shown in analysis No. 8 of Table G.

Below St. Stephens there is deep water to Mobile, with the exception of one bar, which may be removed without much trouble or expense.

Oven Bluff.—From Hobson's quarry, just above the Lower Salt Works Landing, down to Oven Bluff, a distance of 2 miles, the orbitoidal limestone or chimney rock occurs at the base of bluffs of Tertiary age.

At the quarry the hard limestone, which is being taken up for riprap work, lies ,as at St. Stephens, just above the soft chimney rock. Along the stretch of river above described this chimney rock is seen in a bed 15 to 20 feet in thickness, just above the river bottom, and is easily accessible. Analysis 2, Table F, of a sample from Oven Bluff will show the quality of the limestone here. As regards clay three varieties have been examined, a residual clay from over the limestone, a swamp-bottom clay from the low grounds of Leatherwood Leatherwood Creek, and clay from strata of the Grand Gulf formation which here overlies the St. Stephens limestone. The analyses of these clays have not yet been made.

The first shoal in the river above Mobile is a few miles above Oven Bluff, so that from this place down there is a 9-foot channel at all seasons, which will give to Oven Bluff a certain advantage over other localities in regard to transportation. The shoal mentioned is one which can be removed, so that St. Stephens may be classed with Oven Bluff as regards transportation by water, except that the former is some miles farther from the Gulf than the latter.

Analyses by Dr. Mallett of other specimens of this chimney rock are here presented. No. 8, Table F, is of a specimen from Colonel Darrington's place, in the lower part of Clarke county near Gainestown, and 9 and 10 are from other localities in Clarke county near the rivers.

Localities along the line of the Southern Railway.—At Glendon station, a few miles east of Jackson, there is an exposure of the chimney rock close to the track. The rock here is about 20 feet thick, and the limestone is covered by a bed of red residual clay similar to that at St. Stephens and Oven Bluff. The same chimney rock may be seen along the road between the station and Jackson, and no doubt it occurs from Glendon up to Suggsville station, within convenient reach of the railroad. At Suggsville station the same rock occurs along the road leading from station to the town. This place is within a short distance of the railroad.

Between Suggsville and Gosport, the country rock is the St. Stephens limestone, but no particular attention was given to it for the reason that no railroad crosses the county along this line.

Along Alabama River.—At Perdue Hill the St. Stephens rock outcrops near the base of the hills which descend to the terrace on which the town of Claiborne stands. The bluff at Caliborne Landing shows near the summit the calcareous clay or clayey limestone which lies at the base of the St. Stephens formation, and which is generally thought to be the equivalent of the Jackson group of the Mississippi geologists. It is quite possible that this rock, where it occurs in sufficient quantity, may be suitable for cement making,, since it has a composition not far different from much of the Rotten limestone or Selma chalk. No investigations have yet been made concerning it, for the reason that there are comparatively few points where it appears in adequate thickness and in favorable localities as regards transportation.

At Marshall's Landing, just above the mouth of Randon's Creek, is the first exposure of the chimney rock along Alabama River. This occurs at the top of the bluff. It has the usual covering of residual clay, and the analyses presented (3 of Table F, and 7 of Table G,) will show the composition of the two. Below the orbitcidal or chimney rock at Marshall's there are 20 feet or more of a porous limestone, the analysis of which is given in Table F, No. 4. In the same bluff there are beds of calcareous clay which might possibly be used in mixing with the limestone. At the landing these would be difficult to quarry because of overlying strata, but they would certainly be found without cover along the bluffs above Marshall's if they should prove of value.

From Marshall's down to Gainestown Landing the river bluffs show beds of the limestone at numerous points. At Gainestown, the topmost bed of the St. Stephens, the hard crystalline limestone occurs not far above the water level in the river. This stone has been cut and polished and proves to be a first-rate marble, inasmuch as it takes a good polish and shows agreeable variations in color. The soft chimney rock underlies the hard limestone here as at other points.

At Choctaw Bluff, some miles below Gainestown, there is the last exposure of the Tertiary limestones on the river. The material is an argillaceous limestone with numerous fossils, but it seems hardly likely to be of use in cement making.

Between Alabama River and the main line of the Louisville and Nashville Railroad.—A few miles east of Marshall's Landing, at Manistee Mills, the terminus of a sawmill road, there is a quarry of the chimney rock, conveniently situated as to transportation, since it is on the railroad. Across the country to the Repton Branch of the Louisville and Nashville Railroad, the St. Stephens limestone may, of course, be found at thousands of places, but no mention is made of these occurrences where they do not lie on railroad line.

Below Monroe Station, near Drewry on the Repton Branch, this road crosses the line of outcrop of the chimney rock, which at a number of points in the vicinity of Drewry lies within easy reach of transportation.

A few miles below Drewry, at Manistee Junction, there is a fine exposure of Grand Gulf clays in railroad cuts, both north and south of the station.

Analysis is given (No. 9 of Table G), of the clays from these cuts, from which their suitability from admixture with the limestone may be determined.

On the main line of the Louisville and Nashville Railroad.—The chimney rock may be found at many points below Evergreen in the vicinity of Sparta and Castleberry stations. There are many bluffs of this rock on the banks of Murder Creek in this vicinity, and there are several quarries from which the stone has been obtained for building purposes, within short distance of the railroad line. At the foot of Taliaferro's Heights the limestone forms high bluffs on the creek; at Ellis Williams Spring there are bluffs with the soft rock at the base and the hard horse-bone rock at the top, and on the creek bank, a few hundred yards away, is one of the quarries mentioned above. In fact the localities where the rock may be found within convenient distance of the railroad, and in a position favorable to cheap quarrying, are numerous in all this region. No clays were seen except the usual residual clays from the decomposition of the limestone and a clay occurring close to Evergreen in the pits of Wild Brothers. Analyses 5, 6 and 7 of Table F, will show sufficiently well the character of the limestone in this section.

The Evergreen occurrences have attracted attention because of their location on the line of a great railroad system within short distance of tide water.

Farther to the east this limestone formation extends across Alabama and into Georgia and Florida, but as there is no north-south railroad east of the Louisville and Nashville at this time, the investigations have gone no further.

To summarize: While the St. Stephens limestone outcrops across the State from the Mississippi line to the Chattahoochee River, often occupying broad belts, attention has been concentrated on those localities which lie upon navigable streams or upon railroad lines terminating in Gulf ports. As compared with the Demopolis division of the Selma chalk, this limestone is more uniform in composition, higher in lime content, softer and more easily quarried and crushed, and in geographical position many miles nearer the Gulf.

Its thickness, on the other hand, is much less, although sufficient to supply an indefinite number of manufactories with raw material for cement.

Table F.

Analyses of Tertiary Limestones.

Locality.	Silica.	Iron and aluminum oxides.	Calcium carbonate.	Magnesium carbonate.	Sulphuric anhydride.	Water and organic matter.
1 St. Stephens orbitoidal limestone, St. Stephens, Tombigbee river; R. S. Hodges, analyst	2.28	2.04	92.85	1.92	.13	....
2 Orbitoidal limestone, "Chimney Rock," Oven Bluff, Tombigbee river; R. S. Hodges	4.18	3.26	89.32	2.38	.15	.81
3 Orbitoidal limestone, Marshall's Landing, Alabama river, Monroe county; R. S. Hodges	2.52	1.50	94.07	1.90	.08	....
4 Limestone underlying the orbitoidal rock, Marshall's Landing; R. S. Hodges	11.44	3.34	80.46	3.09	.15	1.52
5 Chimney Rock, Taliaferro's Heights, near Evergreen, Conecuh county; R. S. Hodges	2.84	2.16	91.31	1.83	.07	1.79
6 St. Stephens orbitoidal limestone, near Evergreen; Dr. W. B. Phillips, analyst	1.26	1.72	96.09	.65	.02	.65
7 Orbitoidal limestone near Evergreen; D. W. B. Phillips	2.75	2.73	93.31	.23	.02	.60
8 St. Stephens orbitoidal limestone, Col. Darrington's, near Oven Bluff, Clarke co; Dr. J. W. Mallet	1.69	2.12	94.84	.96	......	....
9 St. Stephens orbitoidal limestone, Clarke co. near river; Dr. J. W. Mallet, analyst	2.44	.27	94.85	......	......	....
10 St. Stephens orbitoidal limestone, Clarke county near river; Dr. J. W. Mallet, analyst	4.15	1.29	93.19	1.09	......	....

Table G.

Analyses of Clays (Cretaceous and Teritary) and Cement.

Number ot anaylsis.	Silica.	Iron and aluminum oxides.	Calcium oxide.	Magnesium oxide.	Sulphuric anhydride.	Total sulphur.	Ignition.
1 Residual clay over limestone, at Demopolis Cement Works; R. S. Hodges, analyst	55.64	26.25	.91	1.97	Tr	....	13.90
2 Residual clay over limestone at P. H. Pitts' Home Place, Uniontown; R. S. Hodges	69.57	19.04	37	......	.....	....	9.68
3 Residual clay, Graveyard Hill, Morgan Place, Uniontown; R. S. Hodges	56.74	28.10	.70	1.27	Tr	....	13.80
4 Residual clay, Reid Place, White Bluff, Alabama river, Dallas co.; R. S. Hodges	56.90	27.71	.86	1.64	.09	....	11.26
5 Residual clay over orbitoidal limestone, St. Stephens, Washington county; R. S. Hodges..............	59.71	24.79	.37	......	.....	....	14.96
6 Residual clay over limestone, St. Stephens Bluff; R. S. Hodges.....	44.94	36.36	5.14	1.20	.....	....	13.77
7 Residual clay over limestone at Marshall's Landing, Alabama river, Monroe county; F. W. Miller, analyst	51.30	33.22	1.37	.96	.41	....	9.42
8 Grand Gulf clay west of St. Stephens, Washington co.; R. S. Hodges	60.68	25.60	.48	.38	Tr	....	9.92
9 Grand Gulf clay Manistee Junc., Monroe county; F. W. Miller, analyst	66.60	25.86	.34	.34	.89	....	5.11
10 Cement manufactured by Alabama Portland Cement Co., Demoppolis; A. W. Dow, U. S. inspector of asphalts and cements, analyst.	20.25	13.44	63.60	1.03	.41	0.99	.....
11 Cement manufactured by Alabama Portland Cement Co., Demopolis analysis from T. G. Cairns, general manager	19.99	13.74	61.36	.61	.....	....	.....
12 Cement manufactured by Alabama Portland Cement Co., Demopolis: R S. Hodges, analyst......	19.99	13.63	63.82	.83	1.16	....	.....

Bulletin No. 9.

GEOLOGICAL SURVEY OF ALABAMA

EUGENE ALLEN SMITH, STATE GEOLOGIST.

INDEX TO

The Mineral Resources

OF ALABAMA.

BY

EUGENE A. SMITH

AND

HENRY McCALLEY.

With Map and Illustrations.

Brown Printing Company,
Montgomery, Ala.,
1904.

omi Sch. of Mines
Metallurgy

4-1924

To His Excellency, Gov. William D. Jelks:

Sir: I have the honor to submit herewith an Index to the Mineral Resources of Alabama.

As the name implies, this document is intended rather to direct the attention of those interested to the various natural resources of the State which are considered capable of being profitably utilized, and to the sources from which more detailed information may be derived, than to be a complete or adequate presentation of the subject.

Very respectfully,
EUGENE A. SMITH,
State Geologist.

University of Alabama,
April 30, 1904.

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LIST OF PUBLISHED REPORTS OF THE ALABAMA GEOLOGICAL SURVEY.

1. Report of progress for 1874; On the Metamorphic Region of Alabama. Eugene A. Smith 139 pages. Out of print.

2. Report of Progress for 1875. Paleozoic Formations of Coosa Valley. Eugene A. Smith. On Coal Mining in Alabama, T. H. Aldrich. 220 pages. Postage, 5 cents.

3. Report of Progress for 1867. Paleozoic Formations of Roup's Jones', and Cahaba Valleys; Eugene A. Smith, with map; Fresh Water and Land Shells, Lewis. 100 pages. Out of print.

4. Report of Progress for 1877-78; On the Tennessee Valley, Brown's Valley, and Warrior Coal Basin; 4 county maps; Eugene A. Smith. 159 pages. Out of print.

5. Report of Progress for 1879-80. Resources of the Warrior Coal Field, between Tuscaloosa and Sipsey Fork. 2 maps. Eugene A. Smith. Tennessee Valley North of the River; Henry McCalley. 158 pages. Out of print.

6. Report for the years 1881-82. Agricultural Features of Alabama; maps and illustrations; Eugene A. Smith. 615 pages. Out of print.

7. Report on the Warrior Coal Field, 1886; Henry McCalley. 571 pages. Out of print.

8. Bulletin No. 1, Fossils of the Tertiary Formation; T. H. Aldrich and O. Meyer, 1886; 9 plates. Out of print.

9. Fresh Water and Marine Crustacea of Alabama; 8 plates; 56 pages, 1888; C. L. Herrick. Out of print.

10. Report on the Cahaba Coal Field; Joseph Squire. Appendix, Geology of Adjacent Valleys; Eugene A. Smith. Maps, 6 plates and many cuts; colored sections; 189 pages; cloth, 1890. Postage, 11c.

11. Coal Measures of the Plateau Region of the Warrior Field; H. McCalley; A. M. Gibson; map and colored sections; 238 pages, 1891. Postage, 5 cents.

12. Bulletin No. 2; On the Phosphates and Marls of Alabama; Eugene A. Smith; 82 pages; 1892. Edition Exhausted.

13. Bulletin No. 3; On the Lower Gold Belt; Wm. B. Phillips; map and illustrations; 97 pages; 1892. Edition exhausted.

14. Bulletin No. 4; Geology of Northeast Alabama and adjacent parts of Georgia and Tennessee; C. W. Hayes; map and illustrations; 85 pages; 1892. Postage, 3 cents.

15. Report on Murphree's Valley; A. M. Gibson, one section, 132 pages; 1893. Postage, 3 cents.

16. Coal Measures of Blount Mountain; A. M. Gibson; map and sections; 80 pages; 1893. Edition exhausted.

17. Geological Map of Alabama with Explanatory Chart; 1893. Edition exhausted.

18. Geology of the Coastal Plain of Alabama; Eugene A. Smith, L. C. Johnson, D. W. Langdon, and others; many sections and other illustrations; 760 pages; 1894. Postage, 18 cents.

19. Report on the Coosa Coal Field; A. M. Gibson; with section; 143 pages; 1895. Postage, 4 cents.

20. Bulletin No. 5; On the Upper Gold Belt; W. M. Brewer; with notes on the most important Rock Varieties; E. A. Smith; G. W. Hawes, J. M. Clements, and A. H. Brooks; 202 pages; 1896. Postage, 5c.

21. Report on Iron Making in Alabama; Wm. B. Phillips; 164 pages; 1896. Edition exhausted.

22. The Valley Regions of Alabama; Henry McCalley.

Part I. On the Tennessee Valley Region; 436 pp; 1896; p. 10c.

Part II. On the Coosa Valley Region; 862 pages; 1897; p. 20c.

23. Report on Iron Making in Alabama; Second Edition; Wm. B. Phillips. 380 pages. 1898. Edition exhausted.

24. Warrior Basin Report and Map; Henry McCalley; $1.00. Map in separate envelope. Numerous folding sections. 327 pages. 1900. Postage, 16 cents.

25. Bulletin No. 6; Preliminary report on the Clays of Alabama, with Chemical analyses and Physical tests of some of the more important; Dr. Heinrich Ries. 220 pages. 1900. Postage, 8 cents.

26. The Plant Life of Alabama; an account of the distribution, modes of association, and adaptions of the Flora of Alabama; together with a systematic Catalogue of the Plants growing in the State without cultivation, by Charles Mohr, PhD. Cloth. Map and two portraits. 921 pages. 1901. Postage, 33 cents.

27. Bulletin No. 7; Preliminary Report on a part of the Water Powers of Alabama, B. M. Hall. Maps and illustrations. 188 pages. 1903. Postage, 6 cents.

28. Bulletin No. 8; Preliminary Report on the Cement Resources of Alabama. Eugene A. Smith. Postage, —

29. Bulletin No. 9; Preliminary Report on the Artesian and Other Underground Waters of Alabama. Eugene A. Smith. Postage, —

30. Index to the Mineral Resources of Alabama. E. A. Smith and Henry McCalley. Maps and illustrations; 79 pages. 1904. Postage, 3 cents.

These publications are mailed, free of charge; (except No. 24, price $1.00,) to Libraries and individuals who may wish to possess them; but applicants should, in each case, forward the amount of postage needed for mailing the Report desired, to

EUGENE A. SMITH,
State Geologist,
University, Ala.

TABLE OF THE GEOLOGICAL FORMATIONS OF ALABAMA.

Recent.....		Soils First Bottom Deposits.	
Quaternary		Second Bottom Deposits. Columbia or Ozark Sands. Lafayette.	
Tertiary...	Pliocene.	Grand Gulf, Pascagoula.	
	Miocene.	Chattahoochee Beds..........	Alum, Bluff, Oak Grove, etc.
	Eocene..	St. Stephens, Claiborne and Buhrstone. Lignitic Clayton or Midway.	
Cretaceous.		Ripley, Selma Chalk. Eutaw. Tuscaloosa.	
Carboniferous.	Upper	—Coal Measures.	
	Lower	Bangor Limestone and Oxmoor sandstone & shales...	Contemporaneous.
		Tuscumbia limestone (St.Louis) Lauderdale chert (Keokuk)....	Ft. Payne chert.
Devonian		—Black shale.	
Silurian.	Upper.—	Red Mountain or Clinton.	
	Lower.—	Trenton or Pelham Limestone. Knox Dolomite—in part.	
Cambrian.		Coosa or Flatwoods Shales. Montevallo variegated shales and sandstones. Aldrich Limestone. Weisner Quartzite.	
Metamorphic and Igneous Rocks...		Talladega or Ocoee Slates—Metamorphic Paleozoic strata; Coal Measures in part. Ashland Mica Schists; Metamorphic Sediments of undetermined age; probably Paleozoic. Mica Schists; older series; probably Pre-Cambrian. Igneous Rocks; granites, diorites, gneisses, etc. of several ages; Pre-Cambrian and Paleozoic.	

CHAPTER I.

MATERIALS USED IN IRON MAKING, AND ASSOCIATED MINERALS.

It is fitting that a document which treats of the Mineral Resources of Alabama, should begin with an account of those concerned in that Industry which has done so much to give to this state its present commanding position in the industrial world, viz., Iron Making.

THE ORES.

The iron ores of Alabama in the order of their economic importance are (1) The Red Ore or Hematite, (2) The Brown Ore or Limonite, (3) The Gray Ore or Magnetite, and (4) Black Band and Clay Iron Stone. Only the two first have been mined on any large scale.

These ores are used in the manufacture of pig iron for foundries, mills and pipe works, and for making basic iron for open hearth steel plants. As a rule, they are too high in phosphorus for making Bessemer steel.

Practically all the ore mined in Alabama is smelted in the state, the shipments out of the state being about equal to what is received from other states.

Alabama stands third in iron ore production among the states of the Union. The product for 1902 was 3,574,474 long tons, which was a little over ten per cent. of the iron ore mined in the United States. This output had a value at the mines at $1.10 per ton, of $3,936,812. This valuation is less than that obtaining in any other state except Texas, the average in the United States being about $1.84 per long ton.

There are 42 coke furnaces and 6 charcoal furnaces in operation in the state. The charcoal furnaces are gradually going out of blast, and will soon be a thing of the past.

In pig iron production Alabama ranks fourth among the states of the Union. This high rank, which will probably soon be exceeded, is due in great measure to the close proximity of the ore, the stone, and the coal needed for the production of the iron. At many points in the Birmingham District these three essentials are obtained within a radius of six miles of the furnaces.

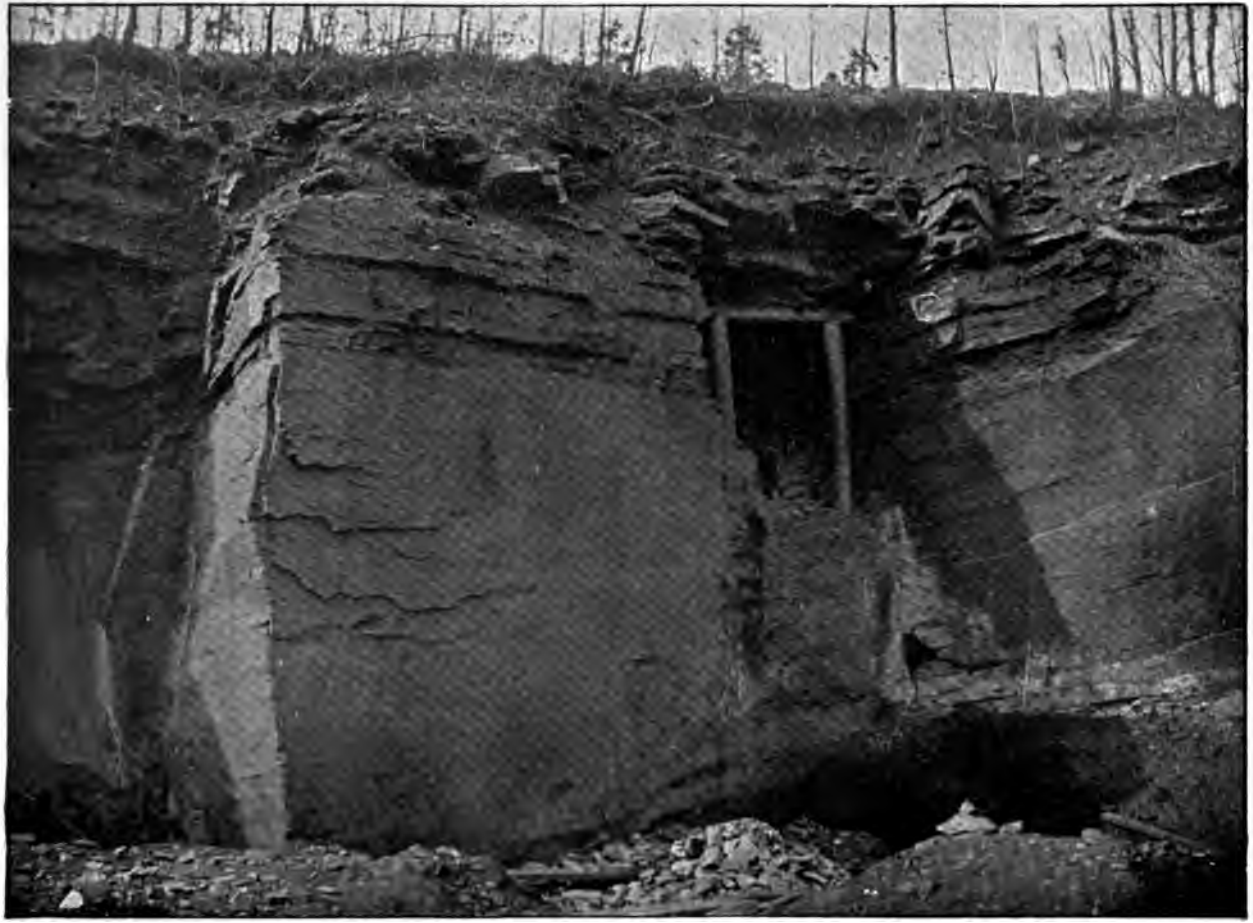
(1.) RED ORE, OR HEMATITE:—While Hematite occurs in Alabama in several geological formations, it is only in the Upper Silurian that it is in sufficient quantity to be of great commercial value. This, the Red Mountain, or Clinton ore, is otherwise known as Dyestone ore, Fossiliferous ore, Oolitic ore, etc. It is the most important iron ore in the state because of its great quantity, the low cost with which it may be mined, its reliability, and its close proximity to the coal and stone used in the manufacture of iron. The output of red ore for 1902 was 2,565,635 long tons, making about 72 per cent. of the iron ore product of the state.

The Red Mountain ridges occur normally on each side of the anticlinal valleys which separate the Coal areas from each other, and are distinguished as East Red Mountain and West Red Mountain. In places the red ore ridges are lacking on one side of the valleys, usually the western side, being cut out by faults, while on the other hand the ridge may be duplicated on one side by the same cause. This *formation* occurs also in the much disturbed strata east of the Coosa Coal Field, in ridges of sandstone and conglomerate which carry no red ore.

In most of the valley occurrences, the moderate dips of the strata are on the eastern side, and the steep dips and faults are on the western side. Murphree's Valley makes an exception to this, the faults and vertical measures being on the eastern side. It is usually the case also that the ore bed shows the highest angle of dip at the outcrop, and that the dip rapidly decreases as the bed is penetrated.

The iron occurs mainly in the central part of the formation, in seams or beds, one to five in number, which vary in thickness from a few inches to thirty feet.

While the ore seams are very persistent along the outcrop, which in Alabama must be as much as 50 miles, yet they vary greatly from place to place, being either too thin or too lean for profitable working in by far the greater part of this distance.



Much mining of red ore has been done near Gate City, Village Springs, Springville, Attalla, Gadsden, Round Mountain, Gaylesville, Ft. Payne, Valley Head, etc., but the most important development of the Clinton ore in the state and in the world, is along the 15 or 16 mile stretch of the East Red Mountain between Birmingham and Bessemer, and there is a practically continuous series of mines, and strippings for this entire distance. The ore here is in three different seams, but the upper fifteen feet of the *Big Seam* or *Red Mountain seam*, have furnished almost the entire supply of ore to the 23 furnaces of the district.

Plate I shows the outcrop of this seam near Birmingham.

In a large part of this stretch of Red Mountain, the ore has been gained by stripping down to where the cover becomes fifteen or twenty feet thick over the ore and too expensive to remove.

Most of the ore, however, is obtained from well developed deep mines going down on the slope of the bed. These mines are equipped with all the latest and most improved devices for the cheap handling of the ore. The deepest of these mines at the present time has gone down on the dip of the bed a distance of 1850 feet from the outcrop. The ore is brought by small mine cars from the different entries to the main slope and there emptied into a skip holding from 12 to 14 tons. The skips are hauled to the surface by steam power, the ore is dumped automatically into the crushers and thence into the railroad cars. This arrangement very greatly increases the handling capacity, and is intended to work to a depth of about a mile. When fully equipped the Red ore mines of the Tennessee Coal, Iron and Railroad company alone will have a capacity estimated at 10,000 tons a day.

The ore of the Big Seam improves in quality towards the southwest, the percentage of lime increasing while that of silica decreases. The percentage of alumina remains about constant, but on account of the coming in of slate partings, more care has to be exercised in the mining.

The lower and major part of the Big Seam has not been worked except very sparingly at the outcrop, being too siliceous, with the silica increasing from top to bottom of the seam.

Experiments carried out by Dr. Wm. B. Phillips for the Tennessee Company, have fully demonstrated the practicability of reducing the relative proportion of silica by magnetic concentration, so that the entire thickness of this great seam will one day be utilized, and the same may be said of the siliceous ores of other parts of the state.

The other seams of the Red Mountain Ore, viz., the *Irondale Seam* below the Big Seam, and the *Ida seam* above it, have been worked at places along the East Red Mountain from opposite Birmingham towards the northeast; the ore is softer than that of the Big Seam, carrying sometimes over 50 per cent. of metallic iron. The Ida seam, where worked, yields a compact ore five or six feet thick, with 30 to 35 per cent. of metallic iron.

In most of the smaller mines the mine cars are hauled to the surface; the miners are paid by the car load (about two tons), the tracks being kept up by the company.

Without any reference to the actual hardness of the ore, the leached red ore containing very little lime is called *soft ore*, and the unleached or limy ore, *hard ore*.

The soft ore is usually hard enough to necessitate blasting and crushing. As a rule it extends down on the dip a distance of 150 to 200 feet from the outcrop, though on the one hand it sometimes extends 300 feet, and on the other hand, in places the hard ore sets in at the outcrop; the amount and depth of the soft ore apparently being more or less determined by the cover. The transition from the one variety to the other is usually abrupt, but the line of contact is irregular, the soft ore extending in points down into the hard ore. Moreover, the soft ore often includes boulders and pockets of the hard ore, and occasionally "horses" of ferruginous sandstone. Both ores are quite contsant in composition away from the line of contact.

The *soft ore* is limited in quantity but this does not signify much, is it is being less and less used in the furnaces. It is usually a mass of smooth, rounded, and flattened grains of quartz of the size of bird shot and smaller, coated with hematite and cemented together by the same material. Its average composition as shown by stock house analyses extended over many years, is about as follows: Silica or insoluble matter 27 per cent: Metallic iron 46 per cent: Water 7 per cent; Phosphorus 0.30 per cent. to 0.40 per cent. and a little lime.

The main dependence of the furnaces of the Birmingham district is the *hard ore.* In the mines it always sets in at the water level, holding its own as to thickness and composition, to the bottom of the deepest mine, 1850 feet, and as far as tested by borings, at least 3,500 to 4,000 feet to the southeast from the outcrop; there seems thus to be no reason for anticipating any adverse change in the ore within the depth to which mining operations are likely to be carried.

When the hard ore carries about equal amounts of silica and lime it is self-fluxing, and under these conditions it has been used alone in the furnaces. Usually, however, it contains more lime than is necessary for self-fluxing, in which case, a little soft ore, or brown ore, or both are added.

At the present time the soft ore makes seldom over ten per cent of the ore burden, though in some of the furnaces it makes half of the burden. From stock house samples the composition of the hard ore is shown to be about as follows: Silica, 13.4 per cent.; Metallic iron, 37 per cent.; Lime, 16.20 per cent.; Alumina, 3.18 per cent.; Phosphorus, .37 per cent.; Sulphur, .07 per cent.; Carbonic acid, 12.24 per cent.; Water, 0.50 per cent.

Red Hematite occurs in Alabama also in the Trenton formation, where it is very similar in quality and appearance to the soft red ore of the Clinton. And in the Cambrian formation still lower in the geological column, it has been observed in stratified seams from 18 inches to 5 feet in thickness.

The Cambrian ore is of the crystallized or specular variety, and may some day be utilized. The known occurrences of it are few in number and none of them has as yet been fully tested.

(2.) BROWN ORE OR LIMONITE. — This ore, the second in importance of the iron ores of Alabama as well as of the United States, furnished only 9.3 per cent of the total iron ore production of the United States in 1902. Of this, Alabama produced 28 per cent, 1,008,839 long tons, and the state leads in this industry.

In the early days of iron making and up to the year 1876 this was the only ore used in the catalan forges, bloomaries, and charcoal furnaces of the state. It was then demonstrated that good iron could be made at low cost from the red ores, with coke for the fuel.

In general the limonites are considered the best of the ores of Alabama and they command the highest prices and command a ready sale.

The usual mode of occurrence is in irregular masses of concretionary origin in the residual clays resulting from the decomposition of limestones, and as a consequence the mining is uncertain and expensive. Limonite also occurs in regularly stratified seams or beds, and then it is the result of the alteration of pyrites or of carbonate ores. Practically all of the brown ore actually mined is that occurring in the residual clays above mentioned. Most of the ore before going to the furnace is washed and screened, and this manipulation, together with the cost of mining, makes it the most expensive of the iron ores, and it is therefore seldom used alone, but is usually mixed with the red ore in proportions determined by the quality of the iron desired. It is used alone in the charcoal furnaces and also in the coke furnaces when a particularly tough pig iron is wanted. Usually the brown ore constitutes about 20 per cent of the ore burden. This addition of brown ore to the red, besides taking care of the excess of lime in the hard red ore, causes a smoother and more uniform flow in the furnace burden, lessening the danger from hanging or shelving.

In a few places a manganiferous limonite occurs, and small quantities of it have been used in the production of spiegeleisen, and ferro-manganese.

The limonite deposits are very numerous and are distributed over a broad expanse of country and in many places are known to be very extensive. In some of the deposits the ore is in nearly solid mass, in others it is much scattered, and in consequence the amount of foreign material necessary to be moved for every ton of ore produced, varies very much, not only in the different ore banks but also in the different parts of the same bank. The mining is in irregular diggings and open cuts, and is mostly done by contract, costing about 75 cents on an average to mine, and bringing about $1.00 per ton at the furnace

Among the varieties of brown ore are the compact, the honey comb, and the ochreous or earthy ores. The pocket ore is nearly always associated with "horses" of clay often pure white and plastic. It is also sometimes mixed with foreign matters such as loose chert, and fragments of sandstone and conglomerate.

The deposits occur in nearly all the geological formations of the state, but in most of these the ore is either insufficient in quantity or not pure enough to be of much commercial value. The most important of the deposits, in point of extent and value, occur in the following formations, viz., the Knox Dolomite and the Weisner Quartzite, the Lauderdale Chert of the Lower Carboniferous, and the Lafayette. Some extensive beds of ore of inferior quality generally, occur also on the Tuscaloosa formation of the Cretaceous, and in the upper part of the Lower Carboniferous and in the Metamorphic rocks.

The Lafayette.—This ore is widely distributed, but does not occur in many places in sufficient quantity and of such quality as to justify working. It is the principal ore of the northern part of the state in the counties of Colbert, Franklin, Marion and Lamar.

Loose boulders scattered over the surface supplied the first furnace in Alabama, which was built in 1818 on Cedar Creek in Franklin county. A Catalan forge must also have been at the same place for lumps of malleable, as well as of cast iron, are to be found around the old furnace ruins.

The furnaces of Sheffield and Florence use this ore without admixture with other ore. Many of the deposits are on high ground and are comparatively shallow, as shown by the diggings extending down to the underlying bedded rocks. Other deposits in lower situations are 50 and 60 feet and more in depth. The ore is mostly a dark colored compact ore, but in in some of the deposits it is of concretionary nature with red and yellow ochres filling the cavities. It occurs in a red sandy loam usually along with rounded pebbles of quartz and often with ferruginous sandstone and conglomerate. This ore, while occurring in the surface red loams of the Lafayette, probably has its source in the Lower Carboniferous limestones and possibly also in part in the stratified seams at the base of the Coal Measures.

In the banks the ore often makes 25 to 30 per cent of the entire mass. It is of good quality as is shown by the following average analysis of washed ore furnished to the Sloss-Sheffield furnaces from the numerous banks about Russellville: Metallic iron 53.67 per cent; Alumina 5.58 per cent; Silica 8.52 per cent.; Phosphorus, 0.33 per cent. It is said to work well in the furnace and to yield an unusually good quality of pig iron, that seldom runs higher than 0.60 per cent of phosphorus and 0.50 per cent of silicon.

The Lauderdale Chert:—The ore of this formation is in stratified seams and pockets. The former are probably the weathered outcrops of carbonate and the pocket ore also, in part at least, from the weathering and breaking down of the stratified seams.

The stratified ore in one or two seams may in some localities be traced for miles where it is too thin or too cherty to be of commercial value. At intervals along these outcrops there are some extensive deposits of boulder, nodular and gravelly ore of good quality, though as a rule inferior to the limonites of some of the other formations. It has never been extensively worked in Alabama. Some of the limonites of this formation are highly manganiferous.

The Knox Dolomite:—The brown ore of the Knox Dolomite is the most abundant, has been extensively mined and, in general, is the best of the iron ores of the state. Some of the deposits have been worked to depth of 100 feet with ore still at the bottom.

The most important deposits and mines are in Cherokee, Calhoun, Talladega, Shelby, Bibb, Tuscaloosa and Blount counties. The ore is found in irregular pockets in the red clay resulting from the decomposition of the limestone of the formation, and while mostly of good quality, high in iron and low in silica and phosphorus, it is sometimes rough and cherty and sometimes a black waxy ore, high in phosphorus. The cherty ore is usually in large boulders, sometimes occurring in rows as if outcrops of stratified ledges.

The view in Plate II of an open cut at Greeley in Tuscaloosa county, illustrates well the mode of occurrence and method of mining the brown ore.

The average composition of the dried ore, as shown by many analyses is, Metallic iron 51.00 per cent; Silica 9 per cent; Alumina 3.75 per cent; Lime 0.75 per cent; Phosphorus 0.40 er cent, and Sulphur 0.10 per cent.

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The charcoal furnaces of the state are wholly supplied with this ore.

The Weisner Quartzite:—The deposits of this formation are numerous and extensive, and are either the outcrops of one or more stratified seams, or a pocket ore derived in part at least from the weathering and breaking down of the stratified seams.

The stratified ore outcrops near the crests of the mountains, (Weisner), while the pocket deposits are mostly near the base of the mountains or along fault lines. The former deposits are very variable, attaining sometimes considerable size, being as much as several hundred yards in length and forty to fifty feet thick. The pocket ore comprises some of the most extensive brown ore deposits in the state. The ore itself is somewhat variable, being in part a black waxy ore high in phosphorus, in part a mixture of very good ore with a highly siliceous or sandy ore.

For this reason the mining is sometimes tedious and expensive because of the necessity of separating the good from the bad. These siliceous or sandy ores are in very large quantities and will no doubt some day be utilized after being concentrated by magnetic process.

(3.) THE GRAY ORE OR MAGNETITE:—This ore occurs in the upper part of the Weisner Quartzite formation in Talladegt county. It is in several stratified seams, one to four, varying in thickness from two to eight feet.

While these seams of ore are generally highly siliceous and hardly more than dark gray sandstone with sparingly disseminated grains of magnetite, yet in places the ore carries as much as 80 per cent of magnetite and only 17 to 18 per cent of silica.

The ore is sometimes massive in structure sometimes laminoted and almost fibrous, breaking up on weathering into fragments that resemble chips of wood. The magnetite is also sometimes in thin scales or plates making a kind of specular ore high in titanium.

The Talladega magnetite has been somewhat extensively investigated and considerable amounts have been raised and furnace tests made, and it is probable that this desirable ore will soon be added to the list of our commercially important resources.

Considerable magnetite has been observed at a number of points in the region of our metmorphic rocks, but as yet not in sufficient quantity to be commercially used.

(4.) BLACK BAND AND CLAY IRON STONE:—The black band is a highly carbonaceous variety of the carbonate ore, occurring at a number of points in the Coal Measures. It has been mined or quarried at only a few places and then only to a very limited extent. Some experiments have been made with it in the furnaces both in the raw and calcined state.

The Clay iron stone occurs in regular seams and in rounded and flattened concretions in the strata of the Coal Measures, and also in the lower Cretaceous and in the Tertiary formations, in none of which, however, has it yet been demonstrated to be of any commercial importance. As result of the weathing and disintegration of this ore are found occasionally some very good deposits of limonite or brown ore.

In connection with iron ores two closely associated minerals may appropriately be described, viz., manganese ores and bauxite.

Manganese Ores.

Pyrolusite and Psilomelane occur in a number of localities in Cleburne, Calhoun, Blount and Cherokee counties in quantity sufficient to make them of probable commercial value.

Several of these deposits in the Weisner formation in Cleburne county have been worked and have furnished probably the greater part of the pure manganese ore that has been mined in the state.

Manganiferous limonite has been mined to some extent near Anniston and converted into *spiegel eisen* and *ferro-manganese* in the Anniston furnaces.

In its mode of occurrence manganese ore is very similar to brown iron ore, with which it is closely associated, most of the brown ore banks containing more or less of it, and it often happens that the same deposit is partly limonite and partly manganese ore. The Blount county deposits of this kind are near the base of the Fort Payne chert of the Lower Carboniferous, those of Cherokee, Tuscaloosa and other counties are in the Knox Dolomite.

Bauxite.

This ore, a hydrate of alumina, is much used as a source of the metal aluminum and of some of its compounds, mainly alum. In this state it occurs, mainly in the Knox Dolomite and in the Weisner Quartzite formations, in irregular deposits along a narrow belt extending from the Georgia line southwestward as far as Anniston. All the deposits thus far known are in the counties of Cherokee, Cleburne, Calhoun and DeKalb, but they are too irregular in their occurrence and have been too little investigated to admit of any close approximation to the quantity of the ore.

The ore is commonly concretionary or pisolitic though sometimes compact, homogenous and fine grained, and the best quality is of gray to white colors. Much of it has iron oxide replacing part of the alumina with the result of giving a reddish and mottled appearance to the ore.

Associated with the true bauxite are mixtures of clay and bauxite in varying proportions, and in places irregular streaks or bands of pure halloysite occur in the midst of the bauxite. The bauxitic clays above mentioned are exceedingly refractory and have been suggested as suitable material for the manufacture of fire brick.

The mode of ccurrence of the bauxite is very similar to that of limonite, in irregular and ill defined pockets, and in some of the limonite banks about Rock Run in Cherokee county, the iron ore appears to grade into the bauxite, and both ores have been obtained from the same digging. Other associations with the bauxite are white china clay and lignite, both of which occur in a bauxite-limonite bank near Rock Run. Manganese ores have also been observed in connection with the bauxite.

The bauxite is obtained from open cuts and pits which are in places 60 to 70 feet deep. It is easily mined, being rather soft below the surface. After sorting and concentrating by screen and hand, it is spread out under shelter and dried by artificial heat before sending to the market, rotary driers being most commonly used. Only the very highest grade of the ore is sold, the lower grades being thrown aside for the present, but the time will probably come when it will all be used in the manufacture of fire brick, as well as of aluminum compounds of various kinds. In the year 1903 only about 6,262 long tons of bauxite were mined in Alabama, as the works were mostly in that part of the deposit lying within the Georgia line. The principal markets are New York, Philadelphia, Pittsburg, Buffalo, Syracuse, Lockport, etc., where are located the aluminum and alum manufactories; and some of the best quality was exported to Germany.

Fuller details concerning the iron and manganese ores and bauxite may be found in the Reports on Murphree's Valley, and on the Valley Regions, Parts I and II, and in the report of Iron Making.

THE COAL.

The termination towards the southwest of the great Appalachian Coal Field, embraces an area in Alabama of about 8,800 square miles.

This area is in three distinct fields separated from each other by narrow anticlinal valleys in which the limestones, iron ores, etc., of older formations than the Coal Measures make the surface. From the main streams which drain them, these fields have been named the Warrior, the Cahaba and the Coosa.

In all three fields the strata have a general dip or pitch towards the southwest, and each is a trough with its axis near the southeastern border; thus the greatest thickness of the measures will be in each field, near the eastern border and at or towards the southwestern end.

The maximum thickness of these measures will not fall short of 4,000 feet. The coal seams vary in thickness from a few inches up to 16 feet, but the thick seams are always more or less shaly. About 25 of these seams have a thickness of 18 inches upwards and have been worked.

Previous to 1874 it has been estimated that the total coal production of Alabama did not exceed 480,000 tons, the earliest mining operations having been carried on in the "forties," in the Trout Creek and Broken Arrow regions of the Coosa field, and in the Montevallo district of the Cahaba field. Since 1874 the production has increased rapidly and in 1903 it was, according to the report of the State Mine Inspector, 11,700,753 tons, valued at about $15,000,000, Alabama ranking fifth among the coal producing states of the Union.

Between two hundred and fifty and three hundred mines on about twenty-five different seams have furnished this coal. These mines vary in annual production from 2,000 to 418,000 tons; more than half of them are drifts with natural drainage; about one third are slopes, and only seven are shafts, the deepest of which is 230 feet. The larger mines are provided with the most modern equipments for mining and raising the coal. The pillar and stall system is the mining method most in use, but the long wall system has been adopted in some cases.

In the year 1903 coal mining gave employment to 12,876 miners and 5,230 day men, using about 100 mining machines in 13 mines. The mines are comparatively free from fire damp which has been detected in about one fourth of them.

The Alabama coals are all bituminous coals, and of quality, as shown by chemical analyses and the practical tests of use, to compare favorably with the coal of other states. By the use of improved shaking screens the coal as mined is separated into lump, nut and slack. The two first go to the general market for steam and domestic purposes, while the slack after washing is used mostly for making coke for the iron furnaces, though some of it is used for blacksmithing. Within the last few years a good deal of *run of mines* from several different mines has been shipped to Demopolis and there used in the rotary kilns of the portland cement plant, for which purpose it has been found to be well adapted.

The principal markets for the coal are within the state, but much of it goes to South Carolina, Georgia, Tennessee, Missippi, Louisiana and Texas; to the steamships at Mobile, Pensacola, New Orleans and Savannah; and to the export trade, chiefly to Mexico.

The home supply is used mainly for manufacture of coke for the iron furnaces, while the commercial shipments are mostly of steam coal which is suplied to almost every railroad in the South.

The growth of the Coke industry in Alabama has been even more rapid than that of the coal mining. It was not until 1876 that it was known that the Alabama Coal would make coke suitable for iron smelting, and the state ranks now second in the Union as a coke producing state.

The coke production in 1903, as given in the Alabama State Mine Inspector's Report, was 2,568,185 tons. The greater part of this coke was used in the iron furnaces of the state, though a portion of it was shipped to other states and to Mexico, for smelting and foundry purposes. The present product does not begin to supply the demand and many new ovens are in course of construction. The coke in 1903 was made in about 8,638 ovens, all of the bee hive pattern except about 240 Semet-Solvay ovens at Ensley, with a daily capacity of about 1,250 tons.

The 80 Semet-Solvay ovens at the Central Furnace near Tuscaloosa were not yet in operation in 1903.

Most of the coke is made from slack coal but the entire output of some of the mines, after crushing, washing and draining, is converted into coke. With one or two exceptions, the heat and gases from the bee hive ovens are allowed to go to waste; but the Semet-Solvay ovens, of course, utilize these products.

At a valuation of $2.45 a ton the coke product of Alabama during 1903 was worth nearly $6,000,000.

THE WARRIOR COAL FIELD.

This field which lies to the north and west of the other two above named, has nearly ten times the area of the two combined, estimated at 7,800 square miles. In the usual classification the Warrior Field comprises all of the coal measures of Alabama, drained by the Warrior and Tennessee Rivers, together with those of Lookout Mountain drained by the Coosa river.

The relatively greater importance of the Warrior Field is due also to the vast amount of coal that can be economically mined within its limits, the coal seams outcropping over great areas and with very moderate angle of dip.

For convenience of description the Warrior Field has been divided into the Plateau Region and the Warrior Basin.

The *Plateau Region* includes the northeastern part of the Field, approximately from the line of the L. & N. railroad to the Georgia and Tennessee borders, together with the spurs of the great Cumberland table land on the western and northern side of the Tennessee river. The name comes from the circumstance that the uplands or mountains are portions of the original elevated table land or plateau into which the valleys have been cut to the depth of 600 to 800 feet. The altitude of these uplands varies from 1200 to 1800 feet above tide water in the northeastern part, to 700 or 900 feet in the vicinity of the L. & N. railroad. The Coal Measures which take part in the formation of these uplands are the strata between the Black Creek Coal Seam and the base of the Coal Measures, embracing about 1800 feet thickness. This full thickness of the plateau measures, including 15 or more seams of coal, occurs along the southern limits of the Plateau region where it merges into the Basin, while near the northern edge adjoining Georgia and Tennessee, there are only about 200 feet of coal strata including one or two coal seams. It will thus be seen that the strata dip towards the southwest at a more rapid rate than does the surface of the country, and the coal measures thicken proportionally in the same direction. The coal seams in the Plateau region are very variable in thickness occurring in bulges and squeezes. Where the strata are thick enough to carry them only about four of the coal seams appear to be always present, only about six of them ever to be of workable thickness, and only two of them of workable thickness in most of their outcrops. In general these plateau coal seams are thickest and most reliable in the northeastern part of this region near the Georgia and Tennessee lines. The coal is usually good, hard, and solid, though sometimes carrying considerable pyrites. Mines have been opened on these seams at a number of places, but the want of uniformity in thickness has prevented any extended operations. In 1903 the production from this region was only about 17,500 tons. These lower seams have furnished all the coal mined in Tennessee and Georgia.

The *Warrior Basin* includes the larger, southeastern part of the field extending in general from the line of the L. & N. Railroad down to where the coal measures pass finally below the Cretaceous formations and appear no more at the surface. As has already been said, the strata dip more rapidly towards the southwestern end of the field than the surface of the country falls away, and the greatest thickness of the measures in consequence is to be found in the southwestern part of the area, in Tuscaloosa county.

The Coal Measures of this region include the strata from the Black Creek coal group to the top of the measures, about 2,-

000 feet, and they contain six groups of coal seams, which, in ascending order, are as follows: the Black Creek group with three seams; the Horse Creek group with five seams; the Pratt group with five seams; the Cobb group with three seams; the Gwin group with two seams; and the Brookwood group with five seams. The seams of a group are seldom more than 25 feet apart, while the groups themselves are usually separated by 200 to 300 feet or more of barren measures. Of the 23 seams above mentioned, 21 have in some of their outcrops a thickness of at least two feet, and may be considered workable. The thickness of the seams varies from a few inches up to 16 feet, but as usual, the thicker seams are more or less shaly. The Warrior Basin furnished in 1903 nearly 10,500,000 tons of the total product, obtained mostly from the seams of the Brookwood, Pratt, Horse Creek, and Black Creek groups, the Pratt and Horse Creek groups furnishing by far the largest proportion. The mines are in nine different counties, Jefferson county alone supplying about 6,250,000 tons, or nearly half the total output of the state. Of the 235 mines, 166 are drifts; 63 are slopes, and 6 are shafts.

Most of the coal of this basin is free burning and good both for steam and domestic purposes and for coking. From the coal of this basin about 2,621,000 tons of coke were made in 1903. As a rule the coal of the Warrior field has a jointed structure by reason of which it breaks into cubical or rhomboidal blocks, though some of it is hard and compact and devoid of this structure. Mineral charcoal is common in the coal of some of the seams, especially west of the Warrior River.

The accompanying view, Plate III, shows a section of the Blue Creek Coal seam of the Horse Creek group, at one of the mines of the Tennessee Coal & Iron Company, in the Little or Blue Creek Basin of the Warrior Basin.

THE CAHABA COAL FIELD.

This is the middle one of the three Alabama Coal Fields. Its length from northeast to southwest is 60 to 70 miles and the width of the upper part about five or six miles, but it widens out towards the southwest, and below the line of the L. & N Railroad it has a width of 12 or 15 miles; the area embraced is about 400 square miles.

The northwestern border of the field is made by the escarpment of Shades Mountain overlooking Shades Valley; the southeastern boundary is a fault of 10,000 feet displacement, by which the Cambrian strata are brought up to the level of the Coal Measures. Along the southern border of the field from Montevallo westward, this fault has overturned a narrow strip of the measures, including several seams of coal.

In structure this field is an unsymmetrical synclinal with its axis very close to its southeastern edge. As a consequence most of the strata of the field have a dip to the southeast almost to the edge of the field, the structure seems to be monoclinal, and the greatest thickness of measures is very close to the eastern border. The wider part of the field, to the southwest of the L. & N. Railroad, is divided by an interior faulted anticlinal which separates the Blocton Basin on the west from the Montevallo and other basins on the east. Minor warpings of the strata have broken the field up into a number of smaller basins.

As with the Warrior Field, so here, the general dip of the field as a whole is to the southwest, and at this end of it we find the greatest thickness of the measures aggregating some 5,500 feet, and holding 50 or more coal seams, half of which have in places a thickness of 2 feet and upwards.

The Maylene basin north of the Montevallo appears to have the topmost measures, and consequently the greatest thickness.

At the present time mining operations are practically confined to the wider southern end of the field beyond the line of the L. & N. railroad, the principal center of production being in the vicinity of Blocton, where at least a dozen mines are in active operation, the Thompson seam being the one mainly worked. East of the interior fault and the measures immediately adjacent to it, much mining is also done in the Montevallo and Maylene basins on the Montevallo and Maylene seams, and along the Southern Railroad also at Glen Carbon, and near Helena on other seams.

The mines of the Cahaba field furnished in 1903 1,781,078 tons of coal. This coal was mined from eight different seams and nineteen mines, eighteen of which were slopes, and one a drift.

As a general rule, the Cahaba coals are of excellent quality. Some of them are the finest steam and domestic coals in the state, and from some an excellent quality of coke is made. The coal of the Cahaba field is in general somewhat harder and cleaner than the Warrior coal, and it is exported to Mexico and South America in large quantities.

THE COOSA COAL FIELD.

This, the smallest, least known and least productive of the coal fields of Alabama, lies to the east of the other two. Like the Cahaba field, it is long and narrow, being sixty miles in length, with an average width of less than six miles, and an area of over three hundred square miles. The southwestern end, like the southwestern end of the Cahaba field, is separated into two parts by a narrow faulted anticlinal valley. The northwestern border of the field is a high mountainous escarpment. The eastern border is made by a fault, which brings Silurian strata up to the level of the Coal Measures. The general dip of the field, as in the other two, is towards the southwest, and the field is an unsymmetrical anticlinal, with its axis close to the eastern edge. We find, therefore, the thickest measures along the eastern edge of the field, and towards its southwestern extremity. It is not easy to determine the thickness of the measures included in the Coosa field, but it is less than in either of the others. The general dip of the strata above mentioned is interrupted at intervals by minor undulations, which have broken the field up into a number of somewhat independent basins. Some seventeen or eighteen seams of coal have been identified in this field, seven or eight of which have in places a thickness of two feet and more. The thickest and most important of these seams occur near the eastern border of the field, and do not underlie very much territory. Mining operations have been carried on mainly at two points, namely, Ragland and Coal City. The output of the field for the year 1903 was 121,000 tons. The coal is remarkably pure, free from dirt and pyrite, and whilst not so hard as the Cahaba coal, is excellent for coking. Some of the earliest mining in the state was done at the two points mentioned.

Those interested will find in the following Reports, published by the Geological Survey, further details concerning the several coal fields:

On the Plateau Region of the Warrior Field; by Henry McCalley.

On the Warrior Basin, by Henry McCalley.

On the Cahaba Coal Field, by Joseph Squire; On the Coosa Coal Field, by A. M. Gibson.

THE STONE.

LIMESTONES AND DOLOMITES.

These rocks which are used for furnace flux and for lime burning are to be found in Alabama in sufficient quantity to satisfy every demand that will ever be made on them.

The fluxing rocks in all the furnaces of the state were exclusively limestones until a few years ago, when dolomite was found to be well adapted to the purpose, and it has since come into very general use in the Birmingham district, where it exists in very convenient proximity to the furnaces. The dolomite as a rule, is of more uniform composition and freer from silica than the limestones, that used in the Birmingham furnaces holding on an average not more than 1.5 per cent. silica, while the limestone will generally average 3 to 4 per cent. The dolomite is therefore better for the making of low silicon pig iron. The purest of the limestone beds are however purer than the best of the dolomite, but the interstratification of ledges of varying quality necessitates much careful selection in quarrying.

The use of limestone as a flux is now again on the increase because of demand for the slag for cement making.

Dolomite.—The most important horizon of the dolomite is the Knox Dolomite of the Cambrian, while the limestones belong mostly to the Trenton of the Lower Silurian and to the Mountain Limestone division of the Lower Carboniferous. All of these have been very extensively quarried to supply the furnaces.

The *Knox Dolomite* as a formation is from 2,000 to 5,000 feet in thickness, the lower part containing some beds of exceedingly pure dolomite, while in the upper part this dolomite is very much intermixed with chert.

The rock used as flux is mostly coarse grained, light gray to dark blue in color, and more or less crystalline in texture.

Dolcito quarry, near Birmingham, is one of the largest in the state, having a capacity of 2,000 tons a day. At the present time it is some 300 yards long and nearly 100 feet in depth at the deepest part. It shows a number of ledges which carry less than 1 per cent. of silica in car load lots.

About one car load a day of selected lump from these ledges is sent to the Ensley Steel Works to be used instead of magnesite in the lining of the furnaces.

The accompanying view, Plate IV, shows the condition of this quarry in 1900.

Other large quarries in the Dolomite are in the immediate vicinity of North Birmingham.

The dolomite from this formation is not used in lime burning though it would no doubt make an excellent lime, as is shown by the lime made of a crystaline dolomite at the Chewacla lime works, in Lee county, near Opelika, where the dolomite of unknown geological age is associated with metamorphic rocks.

Limestone.—The most extensively quarried limestone is that occurring in the Lower Carboniferous formation and generally known as the *Mountain Limestone.* In the northern part of the state this rock is 350 to 1,300 feet in thickness, and covers a great area. In the southeastern part of the region of their occurrence these limestones become very slaty and sandy.

The purer portions of this limestone carry from 95 to 99 per cent. carbonate of lime, but with the better quality of the rock, shales are often interstratified and in the lower part of the formation, the limestone is highly siliceous and of dark blue color.

The Mountain Limestone, as the name indicates, often occurs on mountain sides above drainage level, and therefore in position admirably situated for extensive and cheap quarrying. The principal quarries are near Blount Springs and Bangor on the L. & N. railroad, and near Trussville and Vann's on the A. G. S. railroad.

The *Trenton* or *Pelham Limestone* of the Silurian is another great limestone formation which has been much used both as flux in the furnaces and in lime burning. This limestone occurs in long narrow belts on the flanks of the Red Mountain ridges on each side of the anticlinal valleys. Sometimes it lies in the valley at the foot of the mountain, sometimes it occurs

high up on the side of the mountain and at times even up to the summit. The rock in its best quality is a compact blue limestone, often highly fossiliferous. Weathered surfaces are frequently marked with furrows called "karren felder" which resemble the furrows which one makes by drawing the outspread fingers over a soft surface of plastic clay. These marks are caused by the dissolving action of the little rills of rain water running down the exposed surface.

The best part of the rock is comprised within the uppermost 200 feet of the formation, the purest ledges carrying from 95 to 98 per cent. of carbonate of lime. With these ledges, however, are interstratified others of less desirable composition.

Some of the quarries on the sides of the mountains show clear faces of the stone 100 feet in height, and hundreds of tons can be thrown down by a single blast. These quarries have all the conveniences of situation above the crushers and railroad tracks, and are admirably located for large production at small cost. One extensive quarry is that of the Sloss-Sheffield company near Gate City.

For lime burning this rock has probably been more extensively used than any other in the state, supplying kilns at Pelham, Siluria, Hardyville, Genadarque, Longview, etc., in Shelby county for the manufacture of the long celebrated "Shelby Lime."

In this connection we may speak of other forms of limestone capable of industrial application, viz., marbles and lithographic stones.

Marbles.

The marbles of Alabama are of two kinds, crystalline or true marble, and non-crystalline.

The *crystalline* or *statuary marbles* occur mainly in a narrow valley along the *western* border of the Metamorphic rocks, extending from the northwestern part of Coosa county through Talladega into Calhoun. The outcrops have a width of about a quarter of a mile and a length of 60 miles at least.

The best as yet known are in Talladega county, and the principal quarries from which the stone has been obtained are in the vicinity of Sylacauga, and near Taylor's Mill, on Talladega Creek. At a number of places within these limits, before the civil war, marble was quarried and worked into monuments chiefly. Since the war very little has been done in this line. The quarries were not sunk to any considerable depth (25 feet) and it is doubtful if any of them has gone below the reach of weathering.

In some places the marbles are defective from streaks of talc and a kind of slaty cleavage, but many fine blocks have been obtained and worked up.

A stone from Gantt's Quarry was presented by the Masons of Alabama to the Washington Monument Society in 1851 to be incorporated in the monument. The quality of the marble was such that it was believed by many to have come from Italy. During the present year the Italian sculptor Moretti, who has designed and modeled the Alabama iron colossus, "Vulcan," has obtained some beautiful granular marble from Talladega, which he has wrought into a number of pieces of statuary which will be on exhibition at the St. Louis Exposition.

There is now in Birmingham from Talladega a block of white marble, 30 feet in length and 3 feet wide and 2 feet thick.

In composition most of this marble is quite pure lime carbonate (97 per cent.) and it has been used as furnace flux in one of the iron furnaces.

Along the *eastern* foot of the Talladega mountain range also there are two places where a crystalline dolomite has been observed, viz., in Chilton county on the banks of the Coosa river and in Coosa county immediately opposite and up the banks of Paint Creek. The other locality is near Elder postoffice, in Clay county. Nothing has been done at either of these localities in the way of developing the stone.

Still further southeast in Lee county near Opelika there is a quarry in white crystalline granular dolomite which has been worked for a great many years for making lime. This is the Chewacla lime works and quarry. This same deposit has been traced for a number of miles both northeast and southwest of the Chewacla quarry, and the stone has been obtained and used in lime-burning at Echols Mill, at Springvilla, etc., but at this time only the Chewacla works are in operation. This stone, while of beautiful white color and granular texture, has in some of the ledges, small streaks of talc also of white color, which would seriously interfere with its use for ornamental purposes. It is probable that some of the ledges are free from this defect.

The *non-crystalline marbles* occur in most of the limestone formations of the state. Under this term we would include those compact limestones which take a good polish and which have an agreeable color and which can therefore be used for ornamental purposes. Rock of this kind has been utilized from the Cambrian formation, from the Trenton, from the Lower Carboniferous, and from two horizons in the Tertiary, viz., at the base in the Midway or Clayton division, and higher up in the St. Stephens limestone.

The Trenton and Cambrian limestones are often beautifully variegated in similar manner to the Tennessee marble. Handsome blocks of this quality have been cut and polished from near Calera, from Pratt's Ferry on the Cahaba River, and from Jones Valley between Bucksville and Bessemer.

No regular quarrying and working has been done except at Pratt's Ferry, but much beautiful stone has been obtained at that point.

The Lower Carboniferous limestones are generally of a grayish color, sometimes oolitic, sometimes packed with fossils which make very pleasing variety in the color and shade in polishing.

The Tertiary limestones, especially the St. Stephens, while usually of open porous texture, hold ledges of hard, almost crystalline rock capable of taking good polish. The colors vary from nearly white through shades of yellowish into red, and it would make a handsome decorative marble for inside work especially. This rock occurs along the banks both of the Tombigbee and the Alabama rivers, at Oven Bluff and St. Stephens, and some intermediate points on the former, and from Gainestown up to and above Marshall's Landing on the latter. It will probably soon be used in cement making and further acquaintance with its varieties, due to extensive working, will no doubt direct attention to those ledges of the formation which will make good marbles.

The dolomites of the Knox horizon are also in part of suitable quality for ornamental work. The geological map of the state will show the distribution of these rocks, which is very extensive. The spots where they have been actually cut and polished are few.

Lithographic Stone.

A bedded limestone of the Lower Carboniferous formation in Jackson county has been quarried on a very small scale, polished and engraved, and prints made therefrom, which are very satisfactory. One of these engraved stones is in the museum of the University.

Some of the dolomites of the Knox formation in the central parts of the state have also been pronounced to be fit for this purpose, but they have not been subjected to the practical test of actual use.

In the Report on the Valley Regions, Parts I and II, will be found other and fuller details concerning the calcareous rocks just described.

CHAPTER II.

CLAYS AND CEMENT.

The industries which in the near future bid fair to rival in importance that of Iron Making, are those connected with the utilization of our vast resources of clay and of cement materials, and these come appropriately next to be described.

KAOLINS, CLAYS AND SHALES.

Many accumulations of clay-like materials, are the insoluble residues left from the decomposition of other minerals and rocks, and when such clays have not been removed far from their parent rocks they are known as residual clays. Some of the purest of clays, *i. e.*, kaolins, are of this kind, resulting from the decomposition of feldspars, and on the other hand residual clays left after decomposition of limestones and of many crystalline rocks, are among the most impure of the clay kind.

Any of these residual clays, from the pure kaolins to the heterogenous mixtures left from limestones, etc., may, by the action of running water, be taken up and redeposited in secondary positions, becoming thus sedimentary clays. In this removal from one place to another, much of the contaminating material may be separated from the clayey matters, and in this way the secondary deposits may occasionally be freer from foreign admixtures than the original residual mass. But, as a rule, the opposite is the case, and the more a mass of clay has been subjected to transportation and redeposition, the more likely it is to take up and incorporate impurities of all sorts.

KAOLINS.

If we use this term to designate only the residual material from the decomposition of feldspars, the kaolins are in Alabama restricted to the area of the crystalline or metamorphic rocks, embracing parts or all of Cleburne, Clay, Randolph, Lee, Macon, Tallapoosa, Elmore, Coosa, and Chilton counties. The kaolins are usually associated with veins of coarse grained granites or *pegmatites* intersecting the other rocks of this region, the kaolin being derived from the feldspars of these granites.

The northwestern part of Randolph and adjacent parts of Cleburne and Clay counties may be considered the central area of kaolin occurrence, though it is not wanting in the other parts of the region mentioned.

Up to the present time none of these deposits has been utilized in a commercial way, but from some of the Randolph county kaolin specimen sets of fine china ware were made and exhibited at the Art Institute Fair in Philadelphia, December, 1900, where they were awarded a premium.

Table 1—Composition of Kaolins.

	Locality.	Silica.	Alumina.	Ferric Oxide.	Lime.	Magnesia.	Alkalies.	Ignition.	Total.
1	Washed Kaolin, 1½ m. N. E. of Milner, Randolph County	47.75	38.00	.20	*	*	*	14.85	100.80
2	Washed Kaolin, 1½ m. S. E. of Micaville, Cleburne County	45.20	38.00	*	.22	*	*	15.90	99.32
3	Kaolin, J. B. Ross, Miller Place, Micaville, Cleburne County	46.88	39.97	.08	.30	*	.64	13.87	101.74
4	Kaolin from S. ½ S. 28, Tp. 18, R. 11 E. Senator McIndoe, Randolph County	42.41	38.33	...	...	.70	...	17.42	......

*Trace.

CLAYS.

These include materials varying in composition from that of the vein kaolins above mentioned to the most impure aggregations having a clay basis.

China Clays.—The clays used in the manufacture of porcelain and fine white earthenware, which, from absence of iron burn white or nearly white at moderate temperatures, are called china clays. Their composition varies between somewhat wide limits, some having very nearly the composition of vein kaolins, while most of them contain a much higher percentage of silica. The china clays are associated with the older formations of the state in Calhoun, Talladega, Cherokee, DeKalb, Etowah, and perhaps other counties, and with the Tuscaloosa formation of the lower Cretaceous in Marion, Colbert, Fayette, Tuscaloosa, and Bibb.

The composition of the various qualities of china clays as yet examined in the state are shown in the appended table of analyses.

Table II—Showing Composition of China Clays.

Locality.	Silica.	Alumina.	Ferric Oxide.	Lime.	Magnesia.	Alkalies.	Ignition.	Total.
1. China Clay, Eureka Mine, DeKalb Co..	47.00	38.75	.95	.70	*	*	12.94	100.38
2. J. J. Mitchell's Chalk Bluff, Marion county	47.20	37.76	*	*	*	*	14.24	99.20
3. Near Kymulga, Talladega county...	50.45	35.20	.80	.60	.62	....	12.40	100.07
4. F. Y. Anderson's, DeKalb county	53.50	34.45	.21	.30	*	.21	13.20	101.87
5. Rock Run, Cherokee county...	60.50	26.55	.30	.90	.65	2.70	7.20	99.50
6. Pegram, Colbert county	64.90	25.25	*	*	*	....	8.90	99.05
7. Briggs Frederick's, Chalk Bluff, Marion county	65.49	24.84	*	1.26	*	*	7.80	99.37
8. J. R. Hughes', Gadsden, Etowah county	67.95	20.15	1.00	1.00	*	1.87	8.00	99.97

*Trace.

Fire Clays.—These are clays which do not fuse when subjected to a high temperature, at least 2700 degrees Fahrenheit. Semi-refractory clays which cannot withstand a temperature of more than 2300 to 2400 degrees are sometimes called fire clays, and are in fact used along with other more refractory clays in the manufacture of certain classes of fire brick. The fire clays of non-plastic character are known as flint clays, and have nearly the composition of kaolinite. The only Alabama material which might be classed as a flint clay occurs very abundantly in the lower Claiborne or Buhrstone formation of the Tertiary. It is, however, a highly siliceous material carrying as much as 85 per cent. of silica, and containing a great number of the siliceous tests or shells of *radiolaria.*

The plastic fire clays are rather widely distributed, occurring in the Cambrian and Silurian formations, in the Lower Carboniferous, and most probably in the Coal Measures, though none has as yet been investigated from that horizon. The Lower Cretaceous or Tuscaloosa formation, which stretches as a belt around the southern and western edge of the older formations, is perhaps the most important in respect of its clays of all sorts. The following table will show the composition of refractory clays from a number of localities, together with their melting points. The bauxites of Cherokee county have been tested as to their refractory qualities and from these tests it appears that they may be advantageously used in connection with refractory fire clays in the making of fire brick. Several analyses and fire tests, of bauxites have been included in the table.

Manufactories of fire brick are located at Bessemer, Ashby, Brickyard, Fort Payne, etc.

Table III.—Composition of Refractory Clays.

	Locality.	Silica.	Alumina.	Ferric Oxide.	Lime.	Magnesia.	Alkalies.	Ignition.	Incipient Fusion, °Fah.	Vitrification, °Fah.
1.	Rock Run, Cherokee County, Cambro-Silurian	47.60	36.70	1.10	1.30	*	*	14.20	3146°	.....
2.	Fire Clay, Rock Run, Cherokee County, Cambro-Silurian.......	34.60	45.80	.52	.....	.....	.....	20.00	†3050°	.....
3.	Low Grade Bauxite, Rock Run, Cherokee Co., Cambro-Silurian.	31.20	44.28	1.45	1.00	.20	.....	22.60	3146°	.....
4.	Low Grade Bauxite, Cambro-Silurian.........................	18.30	54.39	1.36	.....	.....	.....	27.60	†3150°	.....
5.	Fire Clay, Peaceburg, Calhoun County, Cambro-Silurian.......	51.90	35.00	.99	.23	.10	.55	11.30	2300°	3150°
6.	Valley Head, DeKalb County, Lower Carboniferous	82.04	12.17	*	*	.33	.60	4.33	2400°	3050°
7.	Fort Payne, DeKalb County, Lower Carboniferous	66.25	22.00	1.60	*	*	.75	9.05	2300°	3050°
8.	Pearce's Mill, Marion County, Cretaceous	52.95	35.10	.80	*	*	.93	11.40	3050°	3150°
9.	Bibbville, Bibb County, Cretaceous...........................	74.25	17.25	1.19	.40	*	.52	6.30	2300°	3050°
10.	M. & O. R. R. cut, W. of Tuscaloosa, Tuscaloosa Co., Cretaceous.	58.13	24.68	3.85	.15	.32	1.78	11.78	2200°	3050°
11.	Siliceous Flint Clay, Choctaw County, Tertiary...............	86.30	5.12	1.60	.46	.....	.....	6.60	2300°	2500°
12.	Fire Clay, Cuba, Sumter County, Tertiary	50.25	35.20	1.80	.50	.30	.45	10.30	2102°	3038°‡

*Trace. †Not affected at this temperature. ‡Above.

Pottery or Stoneware Clays.—Stoneware clays are intermediate in their nature between fire clays and pipe clays, that is too impure for the one purpose and too good for the other. In the manufacture of stone ware it is essential that the clay should burn to a dense impervious body at not too high a temperature, and the color after burning should be uniform and good, if the ware is to be unglazed or is to be coated with a transparent glaze. Clays suitable for stone ware occur in the older formations, Cambrian, Silurian, Lower Carboniferous, and in the Lower Cretaceous or Tuscaloosa. This remark applies rather to the clays which have been investigated by the Geological Survey, and it should be understood that stoneware clays occur in other formations and in other parts of the state than those from which the subjoined examples have been taken.

In the table showing the composition we have given such notes as to color and character assumed in the burning, as will assist one in arriving at a correct estimate of the properties of the clays.

Table IV—Composition of Stoneware Clays.

Locality.	Silica.	Alumina.	Ferric Oxide.	Lime.	Magnesia.	Alkalies.	Ignition.	Remarks.
1. Stoneware Clay, Blount Co., F. S. White	61.50	26.20	2.10	0.50	0.43	0.70	7.29	At 2200° Fah. burns to dense body—cream color. At 2350° vitrifies—light gray color.
2. Pottery clay, Rock Run, Cherokee Co. C. C. Davenport......	57.00	17.80	5.60	2.10	1.20	6.00	9.45	At 2150° Fah. fuses to transparent glass, suitable for natural glaze.
3. Pottery clay, McLean's, Elmore County	62.60	29.98	.72	.40	.36	.65	8.60	Burns to dense, smooth, bluish white body. Vitrifies at 2150° Fah. Viscosity at 2400° Fah.
4. Pottery clay, Tuscaloosa Co., H. H. Cribbs	65.35	21.30	2.72	.60	.86	*	8.79	Burns to dense yellowish body. Vitrifies at 2200° Fah. Viscosity at 2400° Fah.
5. Pottery clay, Pegram, Colbert County, J. W. Williams......	66.45	18.53	2.40	1.50	1.25	*	8.68	Burns to dense yellowish white body. Vitrifies at 2300° Fah. Viscosity at 2500° Fah.
6. Pottery clay (refractory) Fayette Co. Shirley's Mill	72.20	17.42	2.40	*	*	.56	7.52	Burns to yellowish white body. Vitrifies at 2200° Fah. Viscosity at 2400° Fah.
7. Pottery clay, Franklin Co., Thos. Rollins	67.50	19.84	6.15	.12	.10	....	7.65	Burns to reddish gray body. Vitrifies at 2100°. Viscosity at 2300° Fah.
8. Pottery clay, Marion Co. 10 m. S. W. of Hamilton	70.00	21.31	2.88	.20	*	*	6.85	Burns to grayish buff color. Vitrifies at 2150° Fah. Viscosity at 2350° Fah.
9. Stoneware clay, Fayette Co., H. Wiggins	63.27	19.68	3.52	1.30	*	1.20	9.80	Burns to dense red body. Vitrifies at 2100° Fah. Viscosity at 2300°.
10. Stoneware clay, Lamar Co., Fernbank	69.50	13.00	6.40	.25	*	*	10.10	Burns to hard dense body of deep red color. Vitrification at 2100° Fah. Viscosity at 2300°.
11. Stoneware clay, Pickens Co., Roberts' Mill	68.23	20.35	3.20	.34	*	.74	7.16	Burns to dense buff body. Vitrification at 2200° Fah. Viscosity at 2400°.
12. Pottery clay, Cuba, Sumter County	50.25	35.20	1.80	.50	.30	.45	10.30	Burns to whitish color, becoming buff at 2354° Fah. Not vitrified at 3038°.

*Trace.

Of the above analyses, Numbers 1 and 2 are from Paleozoic formations; Numbers 3 to 11, inclusive, are from the Lower Cretaceous, (Tuscaloosa), and 12 is from the Tertiary, and they have been selected from a great number to illustrate the wide distribution of clays of economic value.

Clays and Shales for Portland Cement Making.—Under the head of Cement Resources, we have given a number of analyses of clays adapted to use in cement making, and add here several others.

These clays, like the preceding, are widely distributed, as may be seen from the localities given, and they are from a great variety of geological formations.

Analyses of a few shales from the Coal Measures are also appended as being very likely to come into use in this connection, not only because of the fitness of the chemical composition, but also on account of their proximity to the Trenton and Lower Carboniferous limestones and to the mines of coal.

While the composition of the limestone which is to be used in the cement manufacture, varies in the different formations, and will in a measure determine the character of the clay which will be suitable to mix with it, yet there are certain limits within which the composition of the clay must fall in order to adapt it to the rotary kiln in the burning of the cement. Ordinarily a clay will give good results which contains as nearly as possible 60 per cent. of silica and about one-third as much, or less, of alumina and iron oxides, the smaller the proportion of iron the better. The clay should not contain more than 2 per cent. of magnesia and as little sulphur as may be. (D. Fall.)

Table V.—Composition of Shales and Clays suitable for Portland Cement making.

Locality.	Silica.	Alumina.	Ferric Oxide.	Lime.	Magnesia.	Sulphur Trioxide.	Alkalies.	Ignition.
1. Carboniferous Shale, Coaldale, Jefferson Co.	57.22	24.72	7.14	0.49	1.88	0.40	....	7.09
2. Carboniferous Shale, gray, Birmingham, Jefferson County	57.80	25.00	4.00	2.10	.80	....	1.80	7.50
3. Carboniferous Shale, yellow, same locality as No. 2..............	61.55	20.25	7.23	*	.99	....	2.25	6.19
4. Hull's Station, A. G. S. R. R., Tuscaloosa Co., Cretaceous...........	61.25	25.60	2.10	.25	.82	....	1.35	8.10
5. M. & O. R. R., 10 m. West of Tuscaloosa. Tuscaloosa County. Cretaceous	58.13	24.68	3.85	.15	.32	....	1.78	11.78
6. Blount County, F. S. White, Paleozic	61.50	26.20	2.10	.50	.43	....	.70	7.29
7. Chalk Bluff, Elmore Co., Cretaceous	60.38	20.21	6.16	.09	.72	....	1.80	10.21
8. Cribb's place, Bedford, Lamar Co., Cretaceous	60.90	18.98	7.68	*	*	....	*	13.36
9. Sand Mountain Cut. M. & O. R. R., Bibb Co., Cretaceous.......	58.50	24.95	4.65	.50	.30	....	.20	.....
10. Same locality as 9...	59.33	25.28	3.37	.80	.10	....	.65	9.50
11. Blue Cut, M. & O. R. R., 10 m. W. of Tuscaloosa. Cretaceous...	62.70	22.80	1.95	.90	.10	....	.70	10.00
12. Reform, M. & O. R.R. Pickens Co., Cretaceous	62.55	24.62	2.40	.30	.20	....	.42	10.00
13. Bluff at steamboat landing. Lower Peach Tree. Wilcox Co. Tertiary	62.10	15.14	3.20	4.90	1.60	....	2.75	9.65

*Trace.

Shales and Clays, suitable for Paving Brick, Pressed Brick, etc.—The Carboniferous shales at Coaldale, and at the Graves Mines near Birmingham, analyses of which have been given in the preceding table, have for a number of years been used in the manufacture of vitrified brick for paving, and have come extensively into the market. In the various clay deposits mentioned above there are clays in abundance, which have been used in making all the finer grades of building bricks.

It seems superfluous to speak of these in more detail, since they and the other kinds of clays are somewhat fully described in Bulletin No. 6, of the Alabama Geological Survey, prepared by Dr. H. Ries, of Cornell University.

THE CEMENT RESOURCES OF ALABAMA.

SLAG CEMENT.

No details are here given concerning the slag cement materials, since they are manufactured products. Attention is directed, however, to the circumstance that our furnaces are daily turning out vast quantities of slag suitable for making cement, and that plants for this purpose are already in active and successful operation.

PORTLAND CEMENT.

Alabama contains large supplies of limestone, chalk, clay and shale well adapted for Portland Cement manufacture, and widely distributed throughout the state. Coal and labor are abundant and cheap, transportation facilities are excellent, and many of the best limestone and chalk localities are situated on navigable rivers, giving ready access and cheap water transportation to Galveston, New Orleans, Mobile, Charleston, and other ports of the Gulf and Atlantic Coasts. This advantage of location will be immensely increased when work is begun on the Isthmian canal, for cement plants located in Alabama will be more than a thousand miles nearer to the Isthmus than their nearest possible competitors.

The limestones and shales of the northern part of the state lie so close to each other and above all, so close to the great coal mines which must supply the fuel, that the establishment of

Portland cement plants near the coal mines would give to this industry in Alabama the same advantages which the proximity of the iron ore, the coal, and the stone has given to the iron industry, and which has placed our state beyond competition.

As a Portland cement mixture, ready for burning, consists approximately of 75 per cent. lime carbonate and 25 per cent. of clayey matter, the material furnishing the lime carbonate is necessarily of more economic importance than that from which the silica and alumina are derived. In consequence, a Portland cement plant is usually located in the immediate vicinity of a suitable limestone, while the clay or shale required to complete the mixture may be brought some distance. In the present statement, therefore, the Alabama localities where cement industries may be developed will be discussed under four headings, according to the limestone available in each locality.

Disregarding limestone formations whose chemical composition renders them unsuitable for use in the manufacture of Portland cement, as well as those whose outcrops are small or badly located with regard to transportation routes, the limestones of four formations may be considered as particularly well adapted for use in cement manufacture. These are:

(1) Trenton limestone (Silurian) of Northern Alabama.

(2) Bangor limestone, (Lower Carboniferous), of Northern Alabama.

(3) Selma chalk (Cretaceous), of Middle Alabama.

(4) St. Stephens limestone, (Tertiary), of Southern Alabama.

1. *Trenton Limestone.*

Areal Distribution.—The Trenton limestone occurs in all the northeast and southwest trending valleys of Northern Alabama, outcropping usually in a narrow belt near the base of the Red Mountain ore ridges, though sometimes occurring high up on the flanks of these mountains, and in some localities underlying considerable areas of lowlands in the valleys, as at Pelham, Siluria, Longview, Calera, Shelby, Rock Springs, etc.

Chemical Composition.—As this rock is extensively quarried for lime burning and for furnace flux, many analyses are available from which it may be seen that it is a rather pure limestone, carrying normally from 1 to 5 per cent. of silica, and from .5 to 1 per cent. of iron and alumina oxides, and from 90 to 93 per cent. of carbonate of lime, with carbonate of magnesia varying from .75 to 3 per cent. It is hence a pure limestone, requiring an addition of one-fourth to one-third of its weight of clay or shale to make a suitable cement mixture.

Table I.—Average Composition of Trenton Limestones.

Locality.	Insoluble silica.	Iron and alumina.	Carbonate of lime.	Carbonate of magnesia.	Sulphuric acid.
1. **Rock Springs Quarry, Etowah Co.**	1.00	.30	97.00	*	*
2. **Gate City Quarry, Jefferson Co.** **Average of five analyses**	3.78	1.90	91.69	....	....
3. **Longview Quarries, Shelby County.** **Average of three analyses**	.44	.16	98.63	.92	....
4. **Shelby Quarry, Shelby County.** **Average of three analyses**	1.81	.77	96.03	1.67	....
5. **Vance Quarry, Tuscaloosa County.** **Average of car load lots**	4.68	1.22	88.85	3.52	....
6. **Calcis Quarry, Shelby County.** **Average of six analyses**	.51	.42	96.72	1.84	....

*Trace.

Physical Character.—It is a compact blue limestone of normal hardness, and would therefore require more power to crush and pulverize it than the softer rocks of the Selma Chalk and St. Stephens limestone, but it is practically free from combined water, and its use would entail no loss of heat in volatilizing moisture.

Accessibility to Clay or Shale.—In all localities of the occurrence of Trenton limestone, the shales of the Coal Measures are in close proximity, and, so far as these have been analyzed, of suitable composition for mixing with the limestone in cement making. The shales from the Graves Mines below noticed, are near the Gate City quarries, and those of the Cedar Grove mines in Tuscaloosa county are close to the limestone quarries at Vance. In both localities the shales are at coal mines in active operation.

Table II—Composition of Shales and Clays near Trenton Limestones.

Locality.	Silica.	Alumina.	Ferric oxide.	Lime.	Magnesia.	Sulph. anhydride.	Alkalies.
1. Graves Coal Mine. Jefferson Co. Gray shale	57.80	25.00	4.00	2.10	.80	....	1.80
2. Graves Coal Mine. Yellow shales	61.55	20.25	7.23	*	.98	....	2.25
3. Cedar Cove Coal Mines, Tuscaloosa Co. Shale above coal seam	58.50	16.17	11.33	1.22	1.17	.77	....
4. Woodstock, Bibb Co. Cretaceous clay	65.82	24.58	1.25	....	....	....	....

*Trace.

2. *Bangor Limestone.*

Areal Distribution.—The Bangor limestone of the Lower Carboniferous, is extensively developed in Northern Alabama, being well exposed along most of the railroads radiating from Birmingham. It is in fact so widely distributed that a detailed geological map would be required to give any adequate idea of the location of its various outcrops.

Chemical Composition.—In the vicinity of Birmingham ,at Blount Springs, at Bangor, at and near Trussville, this limestone has been extensively used as a flux in the furnaces. In consequence, numerous analyses are available, and very close estimates can be made both of its normal composition and of probable deviations from the normal. These analyses show that the Bangor limestone will usually carry 92 to 98 per cent. lime carbonate; 1 to 5 per cent. of silica; and 1 to 2 per cent. alumina and iron. Normally it does not contain over 1½ per cent. magnesium carbonate, though one exceptional analysis shows a little over 8 per cent. of that constituent.

It may, therefore, be considered as a very pure limestone, and available for use in Portland cement making; requiring the addition of one-fourth to one-third of its weight of clay or shale.

Table III.—Composition of Lower Carboniferous (Bangor) Limestone.

Locality.	Silica.	Iron and alumina.	Carbonate of lime.	Carbonate of magnesia.	Sulphur.
1. Fossick's Quarry, Rockwood, Ala. Average sample	.50	1.45	96.58	2.58	....
2. Blount Springs Quarry. Average five analyses. J. R. Harris	.95	1.01	96.25	1.27	.03
3. Vann's Quarry, near Trusville. Average of six analyses. J. R. Harris......	.81	.63	07.05	1.00	.02
4. Worthington Quarry, near Trussville. Av'ge. of 2 analyses by C. A. Meissner	2.64	2.31	87.51	4.20	....
5. Compton Quarry, Murphree's Valley. Stock house sample. Dr. W. B. Phillips	2.80	.70	94.59	....	....

Physical Character.—The Bangor limestone is a limestone of normal hardness, and cannot therefore be quarried so readily and so cheaply as the Cretaceous and Eocene limestones to be discussed later. Limestones resembling the Bangor in hardness are successfully utilized in Portland cement manufacture in New York, Ohio, Indiana, Missouri, and other states; so that this character alone need not be considered as rendering it unavailable. Its hardness is, moreover, largely counterbalanced by the fact that as quarried it will be practically free from water, and will, therefore, require the expenditure of little coal for complete drying.

Accessibility to Clay or Shale.—Thick deposits of shale of Coal Measures occur near the outcrops of the Bangor limestone in the vicinity of Birmingham. In some parts of the valley to the northeast of Birmingham excellent beds of clay at the base of the Lower Carboniferous formation, are quite extensively developed. Both the overlying shales and the underlying clays have been worked to some extent in this region, the product being used in brick and pottery manufacture. Examination of a series of analyses of these shales and clays as well as of some clays belonging to the Cretaceous formation and occurring in close proximity to some of the limestone quarries in the Tennessee Valley, shows that all of these deposits could fur-

nish material suitable for admixture with the limestone, the underlying clays being apparently slightly better in composition than those of the shales of the Coal Measures above the limestone. The Cretaceous clays appear to be entirely suitable.

Table IV.—Composition of Clays and Shales near Lower Carboniferous Limestone.

Locality.	Silica.	Alumina.	Ferric oxide.	Lime.	Magnesia.	Sulph. anhydride.
1. Ft. Payne, DeKalb Co. Lower Carboniferous clay	66.25	22.90	1.60	....	....	....
2. Colbert Co., Pegram. Cretaceous clay	66.45	18.53	2.40	1.50	1.25	....
3. Colbert Co., Pegram. Cretaceous clay	64.90	25.25	*	*	*	....

*Trace.

The shales and clay in Table II above are also available for the Bangor limestone.

3. *The Selma Chalk (Cretaceous), of Middle Alabama.*

Areal Distribution.—The Selma Chalk or "Rotten Limestone" outcrops as an east and west trending belt, Eutaw, Selma and Montgomery, being near its northern, and Livingston, Linden, Union Springs, near its southern border. In its widest portion, towards the western part of the state, this belt is about 25 miles from north to south, but it thins to the eastward, disappearing entirely some 15 miles west of Columbus, Ga. The belt is intersected by the Alabama, Tuscaloosa, and Tombigbee rivers, and a characteristic bluff of this rock is shown in Plate V, a view of the left bank of the Tombigbee River at Demopolis.

Chemical Composition.—The Selma Chalk is about 1,000 feet in thickness, and is in general terms a very argillaceous, chalky limestone, varying considerably in the proportion of clayey matters in its different parts. In the upper and lower thirds of the formation, the proportion of clay is high and carbonate of lime will not usually exceed 60 or 65 per cent.

The rock of the middle third of the formation, which is the part best suited for cement making, will average about 70 to 85 per cent. of carbonate of lime, and 30 to 35 per cent. of silica, alumina and iron. Its magnesia content is low, well within the requirements for a Portland cement material.

The limestone in some localities shows a considerable amount of iron pyrites, however, which will cause the resulting cement to carry a relatively high percentage of sulphates.

The highly argillaceous character of the Selma Chalk has the advantage that but little additional clay will be required to make a perfect Portland cement mixture.

In the table below, in addition to the analyses of rock containing from 75 per cent. upwards of carbonate of lime, others have been added of rock carrying less than 75 per cent. of this ingredient, and which by proper mixture with the higher grades of rock might make a cement mixture without the addition of any clay.

Table V.—Composition of Selma Chalk.

Locality.	Insoluble matters.	Iron and alumina.	Carbonate of lime.	Carbonate of magnesia.	Sulph. anhydride.
1. Roberts' place, near Gainesville, Sumter County	19.10	3.70	75.57	1.24	.69
2. Jones' Bluff, Tombigbee River, at Epes, Sumter County	9.44	1.76	86.28	1.02	....
3. Bluffport, on Tombigbee River, Sumter County	11.68	1.82	85.10	1.25	....
4. McDowell's Bluff, Tombigbee River, Sumter County	6.06	1.62	90.40	1.15	....
5. Material used in Alabama Portland Cement works near Demopolis, Marengo County	12.50	2.76	80.71	1.05	1.62
6. Van Dorn Station, east of Demopolis, Marengo County	14.36	2.80	80.47	1.30	....
7. Uniontown, Perry Co., Pitt's place....	16.18	3.08	75.35	1.35	....
8. One mile S. of Uniontown, Perry Co.	12.14	2.60	83.65	1.53	....
9. R. R. cut, Milhous Station, So. R'y. Dallas County	15.30	2.44	80.10	.98	....
10. Bluff at Gainesville, Sumter Co.....	18.42	10.79	65.21	1.57	.30
11. Hatch's Bluff, Tuscaloosa River, above Demopolis, Hale County......	41.18	4.16	44.78	2.68	....
12. Selma, Dallas County, Boat landing, Alabama River	16.16	11.22	65.08	2.42	1.40
13. O. M. Cawthon, near Selma, Dallas County	28.40	3.68	64.10	2.58	.08
14. Cahaba, Dallas Co., Alabama River..	31.04	2.94	64.37	.79	....

Physical Character.—The Selma Chalk is soft, and may therefore be easily and cheaply quarried and pulverized. In this respect it is probably the most satisfactory cement material in the United States. Enough should be quarried in dry weather, however, to carry the plant entirely through rainy seasons, for the chalk takes up water easily, and the expense of removing this absorbed water would be considerable.

Accessibility to Clay.—Clay beds are adajcent to, and in some cases immediately overlying, the Selma chalk. These clays, which are probably residual in origin, are in general very suitable for use, in connection with the limestone, in making up the cement mixture. It seems probable that in no case will a plant, located on the Selma chalk, have to go more than a few hundred yards to obtain the necessary supply of clay.

Table VI.—Composition of Clays near Selma Chalk.

	Silica.	Iron and alumina.	Calcium oxide.	Magnesia oxide.	Sulphuric anhydride.
1. Residual clay over chalk rock, Demopolis, Marengo County. Used in cement works	55.64	26.25	.91	1.97	*
2. Residual clay over chalk rock, Uniontown, Perry County. Pitts place	69.57	19.04	.37	....	....
3. Residual clay over chalk rock, Uniontown, Perry County. Morgan place.	56.74	27.90	.70	1.27	.13
4. Clay on Read place, White Bluff, Dallas County, on Alabama River	56.90	27.71	.86	1.64	.09

*Trace.

Besides the residual clays above noted, and which are nearly everywhere available over the chalk, it seems entirely practicable to use mixtures in varying proportions of the purer forms of the chalk as shown in analyses of Table V, Nos. 1 to 9, with more argillaceous varieties such as those shown by analyses 10 to 14. In this way a proper cement mixture might be obtained without the use of clays, where they were difficult to obtain.

4. *The St. Stephens Limestone (Eocene), of Southern Alabama.*

Areal Distribution.—The St. Stephens limestone outcrops in a belt 10 to 15 miles wide (from north to south) in Southern Alabama. The counties of Geneva, Covington, Conecuh, Escambia, Monroe, Clarke, Washington, and Choctaw are in part within this belt.

The high bluff at St. Stephens on the Tombigbee River shown in Plate VI, illustrates well the general characters of the outcrops of this rock along the banks of the Tombigbee and Alabama Rivers.

Chemical Composition.—Most of the St. Stephens beds are slightly argillaceous limestones, less clayey than the Selma chalk; while occasional beds of pure limestone occur. Both types could be utilized in Portland cement manufacture; the purer limestones requiring the addition of more clay than would the argillaceous beds.

Table VII.—Composition of the St. Stephens Limestone.

Locality.	Insoluble matters.	Iron and alumina oxides.	Carbonate of lime.	Carbonate of magnesia.	Sulphuric anhydride.
1. Bluff at St. Stephens. Washington Co..	3.38	1.04	92.85	1.92	.13
2. Oven Bluff, Tombigbee R., Clarke Co....	6.06	1.38	89.32	2.28	.15
3. Marshall's landing, Alabama River, Monroe County	2.82	1.20	94.07	1.90	.08
4. Taliaferro's Heights, near Evergreen, Conecuh County on Murder Creek....	4.04	.96	91.31	1.83	.07
5. Near Evergreen, Conecuh County	1.26	1.72	96.09	.65	.02
6. Near Evergreen, Conecuh County	2.75	2.73	93.31	.23	.02

Physical Character.—In physical character the St. Stephens limestone varies from a soft chalky material, like the Selma chalk, to a rather hard limestone which in some localities takes a good polish and makes a very fair quality of marble. The softer beds could be quarried and crushed as readily as could

the Selma chalk; even the harder beds will not be so expensive to handle as the Bangor or Trenton limestones of Northern Alabama, or as many limestones now worked for Portland cement in the Northern states.

Accessibility to Clay.—Residual clays from the decomposition of the St. Stephens limestone are usually present over most of the beds of this rock. These clays are in general quite similar to the residual clays of the Selma chalk, as may be seen by the appended analyses.

But in most of its territory, the St. Stephens limestone is mantled by the strata of the Grand Gulf formation, which includes beds of clay of considerable thickness and extent, and of quality adapted to the purposes of cement manufacture. The analyses of some of these clays will show their chemical character. The samples taken for analysis are from beds that occur in the immediate vicinity of the limestone outcrops, and either on navigable river or railroad line.

Table VIII.—Composition of Clays near St. Stephens Limestone.

Locality.	Insoluble matters.	Iron and alumina oxides.	Carbonate of lime.	Carbonate of magnesia.	Sulphuric anhydride.
1. St. Stephens Bluff, Tombigbee River, Washington County. Residual clay over limestone	59.71	24.79	.48	....	....
2. Marshall's Landing, Alabama River, Monroe County. Residual clay over limestone	51.30	35.22	1.37	.96	.41
3. Clay of Grand Gulf Formation, Manistee Juncn., L. & N. R. R., Monroe Co.	66.60	25.86	.34	.34	.89
4. Grand Gulf clay, St. Stephens, Washington County	60.68	25.60	.48	.38	*

*Trace.

The Fuel.—The question of a cheap fuel will be an important one for the limestones of the Coastal Plain and while these rocks occur along the banks of the Tombigbee and Alabama Rivers or on railroad lines, yet the high rates of freight make it difficult to get the coal from the fields of Northern Alabama at a price that would insure the success of a plant. This in time will correct itself, but meanwhile the beds of lignite, which are numerous and of sufficient thickness at many points contiguous to the limestone outcrops and to the navigable streams, are well worth careful testing as to their suitability for use in this manufacture. It seems probable that gas might be made from them which would replace the high grade coals, and thus start up a new industry in this section of the state.

Those interested in this subject are referred to a special Bulletin on the Cement Resources of Alabama, published by the Geological Survey, and to a chapter on the same subject published by the United States Geological Survey, in Bulletin No. 225.

NOTE.—In the preparation of this account of the Cement Resources, the writer has had many valuable notes and suggestions from Mr. Edwin C. Eckel, of the United States Geological Survey.

CHAPTER III.

MISCELLANEOUS.

In this chapter will be considered those minerals upon which minor industries are based, or which give promise of being capable of being turned to profitable account.

Gold.

The gold ores of Alabama occur in the northwestern three-fourths of the region of the Metamorphic and Igneous Rocks, mainly in Cleburne, Clay, Talladega, Coosa, Chilton, Elmore, Tallapoosa, and Randolph counties. The area included is something like 3,500 square miles. The gold deposits are not uniformly distributed through this territory, but occur in several roughly parallel belts having a general northeast southwest direction. The ore bodies in Alabama as elsewhere, are quartz veins of the bedded or segregation type, occurring usually in feebly crystalline or semi-crystalline schists, often wrongly called talcose schists, though the term *talcoid* might profitably be used in describing them. Dikes of igneous rocks, granites, and diorites especially, are very commonly observed in the immediate vicinity of the gold veins. The quartz veins are sometimes of lens shape, and of considerable size, sometimes not thicker than the hand, and are apt to be in clusters or groups, the members of which are separated by barren rocks.

At times the quartz veins are associated with mica schists and other well crystallized rocks and occasionally the slates themselves in the immediate vicinity of the veins are gold bearing. Such slates hold often a great number of small quartz lenses the fillings of small fissures or parting in the slate, due generally to movements caused by the intrusion of igneous rocks. In many places the slates with numerous small quartz veins are highly graphitic, and in one locality at least, in Clay county, the gold bearing graphitic slate contains well defined and determinable Carboniferous fossils (*lepidostrobus.*)

The gold ores run in value from a mere trace of gold to $500 a ton, but the richest ores are thin. Where the ore body consists of thin lenses in gold bearing slates the values seldom run higher than $2.00 a ton.

Above the water level these ores are all free milling, porous, friable and usually iron stained, at times showing free gold to the eye.

Below water level are the sulphurets in Alabama as elsewhere.

The quartz veins vary in thickness from a few inches to 50 feet, while the ore bodies consisting of thin lenses imbedded in the impregnated slates are sometimes several hundred feet thick. All these ore bodies maintain their values with the depth so far as they have been worked.

In addition to the above, there are a few placer deposits of much importance, and decayed rock, *saprolite,* from which gold may be obtained by merely washing.

Perhaps the most prominent and persistent of the ore leads is that known as the Devil's Back Bone, crossing Tallapoosa county near its northwestern border. In this the quartz veins are from 6 to 50 feet in thickness, and in the immediate vicinity of this ridge are several large ore bodies consisting of quartz lenses in impregnated highly graphitic slates without any well defined wall. The Back Bone is the most southeasterly of the gold belts and is probably the richest.

Only one of the belts of fully crystalline rocks, viz., the most northwesterly, carries any gold deposits of consequence, so far as is yet known.

Mining operations of greater or less magnitude have been conducted in more than 100 localities in the following counties: Tallapoosa, Cleburne, Randolph, Clay, Talladega, Coosa, Chilton, and Elmore.

In Tallapoosa county there are over 30 of these mines, the most important being in the Silver Hill, Goldville, Hog Mountain, and Eagle Creek districts.

Cleburne county has nearly thirty gold mines, the most important being in the Arbacoochee, Chulafinnee, Kemp's Creek, Turkey Heaven, and Kemp Mountain districts.

In Randolph county there are more than 20, mainly in the Goldberg, Pinetucky, and Wedowee districts. Clay county has half a dozen, all in the Idaho district. Talladega has several in the vicinity of Waldo. Coosa has several in the vicinity of Rockford, and about Parson's Mines. In Chilton county the mining has been done on Blue Creek and Rock Creek, and in Elmore only on Peru Branch.

To the series of semi-crystalline slates, which are demonstrably metamorphosed sediments, we have in Alabama given the name of Talladega slates, and they correspond in appearance and geographical position to the Ocoee of Dr. Safford in Tennessee. These have very generally been deemed older than the Cambrian, notwithstanding strong suspicion, lacking convincing evidence, that they were metamorphosed Paleozoic strata. The finding of Carboniferous fossils in one of these belts, eight or ten miles from its western border, has made it certain that some of the so-called Talladega slates are of Paleozoic age, and probable that all of them are.

More than two-thirds of the gold workings of the state are in the Talladega slates, of which there are four separate belts of unequal width, the two being farthest to the northwest being the largest, and perhaps least important. They run together near the Georgia line. The other two belts are narrower and shorter, but at the same time more important. They are the Silver Hill and Goldville belts. To the former belong the Silver Hill, Mass, Garrett, Long Branch, Blue Hill, Farrar, Gregory Hill, Nicholls, Gold Hill, Bonner-Terrell, Eagle Creek, and other mines less well known.

The Goldville belt carries the numerous mines about Goldville, Goldberg, Hog Mountain, and Turkey Heaven, and those about Wedowee.

The Talladega or Terrapin Mountain belt carries the Parsons and Kemp Creek mines near the eastern border and the Riddle's Mill, Story, Woodward, and other mines near the western border. The mines and placers of Arbacoochee and Chulafinnee are also near the southeastern edge of this belt. Most of the mines alluded to above are mere surface diggings and shallow shafts, many of them put down prior to the great California gold excitement in 1849. The placers of Arbacoochee and Chulafinnee, and Long Branch are the most important, and work has been going on in them continuously for the past 60 years, since they always yield some returns for the labor expended on them. Very fair nuggets are obtained from Arbacoochee every year, by sluicing and panning.

Mining on the quartz veins has been carried on in a very unscientific way, and hardly ever beyond the water level. Until the past year or two no plant has been in operation for working the sulphurets. One establishment of the kind using the cyanide process is at Hog Mountain, and is meeting with success.

Most of the early mining of quartz veins was done years ago in the Goldville district and a line of old pits and shafts may still be seen along a distance of 12 miles or more. Extensive workings were also in the old time carried on about Silver Hill. Pinetucky also was one of the early mines, and it has been in continuous operation to the present time. The Pinetucky shaft is about 100 feet deep.

Gold mining in Alabama has not been as yet one of the paying industries, a fact due as we believe mainly to the insufficient capital and inadequate methods and appliances in use. The experiment at Hog Mountain will, therefore, be watched with interest.

Recently at Kemp Creek postoffice, in Cleburne county, extensive preparations have been made for the hydraulic working on a large scale of some very promising placer deposits. Water is brought a distance of four miles by ditch and flume, and the successful outcome of this enterprise will no doubt lead to the establishment of similar plants in other places.

In conclusion, we may say that the gold fields of Alabama offer inducements to capitalists, since there are very extensive deposits of ore, low grade, it is true, but of such extent and so easily and cheaply mined and milled, that there seems to be little doubt of the result if the working be done on sufficiently large scale and with the most improved methods and those best adapted to the character of the ores.

In Bulletins 3 and 5 of the Geological Survey will be found more detailed information regarding the gold region, and the material is now nearly all in hand for a final report on the subject.

Copper Ore and Pyrite.

Pyrite.—Along the eastern base of the range of mountains known as the Talladega Mountain, there is a belt of greenish rock, resulting from the alteration of an igenous rock, and to this we have given the name Hillabee Schist. Its outcrops have been followed from Chilton county west of the Coosa river, northeastward through Coosa, Clay, and Cleburne counties to the Georgia state line. At intervals along this entire distance there are occurrences of pyrite in the form of crystals disseminated throug the mass of rock; and in beds more or less compact of crystalline pyrite. From near Dean postoffice, in Clay county, northeastward for several miles, the bed of pyrite appears at its best, being several feet in thickness and quite free from impurities.

This bed was first worked for copper, of which it holds a small percentage, and at the Old Montgomery Copper Works, there was considerable activity during the war between the states in manufacturing blue stone and perhaps other copper salts. The remains of the furnaces and other buildings are still to be seen.

Recently the Alabama Pyrites Company has begun work on this vein which averages six feet in thickness, and extends along the outcrop about one and a half miles. The analyses show an average of 42 per cent. of sulphur.

At present the workings go down about 450 feet, and the daily capacity is 150 tons. A railroad has been completed from Talladega to Pyriton, the station at the mines.

In the southeastern part of Clay county near Hatchet Creek postoffice, and at the old McGhee copper mines, there are other occurrences of the pyrite, and at the first named locality considerable work has been done in raising and shipping pyrite. These localities are not yet on a railroad line, and the hauling of the pyrites in a wagon over the mountain can hardly be done without loss.

Copper Ore.—As has been intimated above, the pyrite of the Hillabee Schist contains a small percentage of copper as a rule, but the amount seems hardly to be great enough to make it a copper ore. Near the southern border of Cleburne county at Stone Hill is the copper mine known originally as Wood's copper mine. A mile or two northeast of this there is another mine known as the Smith copper mine. The discovery of copper here was made about 1870, and a great deal of work was done during 1874-5 and 6. The main body of the ore consists of chalco-pyrrhotite and chalco-pyrite, along with a good deal of pyrite containing very little copper.

As is the case elsewhere, the first mining here was in the rich decomposition products of the weathered parts of the vein and for several years these ores were hauled in wagons to Carrollton, Ga., and shipped thence to Baltimore for smelting. With the partial exhaustion of these surface ores smelters were erected at the mines, and from 1876 to 1879 the shipments from the mine were in the shape of ingots of copper. From 1879 to 1896 work was suspended; but in the last named year a new company was organized, "The Copper Hill Mining Company," the old mines were pumped out, a new house was erected over the slope, new machinery put in, and the mining was resumed, and a large amount of ore was brought out and stored around the opening, where most of it still remains, for no smelters were erected, and for want of railroad facilities the ore could not be profitably shipped. The new workings showed the ore body at a depth of 80 feet and below to be some 24 feet thick between walls of igneous rock of the general nature of diorite. Analyses show that the ore is richest near the two walls and that some ten feet of the ore will average 7 per cent. of copper, while the entire ore body will average probably 3 per cent.

Comparatively little mining has been carried on at the Smith mine.

Graphite.

This substance is very generally distributed among the metamorphic or crystalline rocks, and it occurs in two modes. In the feebly crystalline schists or slates which we have called the Talladega, and which in part, at least are paleozoic sediments, of as late age as the Coal Measures, the graphite is very often found as a sort of black graphitic clay free from grit and is frequently used as a lubricant. In this condition the graphite is very difficult to separate from the other matters with which it is mixed. Examples of this mode of occurrence are to be seen near Millerville, in Clay county, and about Blue Hill and Gregory Hill, in Tallapoosa.

In the mica schists and other fully crystalline rocks of this region the graphite is present in the form of thin flakes, or *lamellae*, and is comparatively easy to separate from the enclosing rock. This variety of graphite has been worked at several points in Clay, Coosa, and Chilton counties.

Some of the graphitic schists hold as much as 20 per cent. of graphite, but the average content is less. The belt of graphitic rocks extends from Chilton county northeastward into Georgia.

In Tallapoosa county a mile below Tallassee there is a third mode of occurrence, or perhaps a modification of the second above described. Here a belt of garnetiferous schist crosses the river in an outcrop of about 100 yards width. In this schist the graphite is found in lenses or flakes which sometimes attain a diameter of two inches. As the rock disintegrates the graphite lenses weather out and are scattered loose over the surface. The same belt or a similar one is to be seen where it crosses Wolf Creek in the northern portion of Macon county.

Mica.

While mica has not been sent from Alabama to the market in anything more than experimental way, yet there is much reason for thinking that a good merchantable article can be obtained at a number of points in Chilton, Coosa, Clay, and Randolph counties. In a belt of mica schists extending through these counties, there are frequent veins of a coarse grained granite or *pegmatite,* in which the constituent minerals, quartz, feldspar, and mica, are segregated in large masses. The feldspar is very generally weathered into kaolin, and it is from these occurrences that we get all the true or vein kaolin. The mica in its turn is present in the form generally of large rough masses or boulders, from which it may be split out in sheets of varying size. In all this belt there are ancient pits or mines in which trees are now growing with diameter of 18 inches.

Around the mouths of these old diggings are great piles of broken-up refuse mica, apparently showing that a large amount of the mineral had been taken from them. In North Carolina, and probably elsewhere, the old mines of this kind have often proven to be the best places for obtaining good mica in modern times, and this fact may serve as a hint to those who contemplate mica mining in this state.

Most work in getting mica has probably been done near Micaville, in Cleburne county, and at the Pinetucky mine, in Randolph. Many tons of mica, some of it in large sheets six to ten inches in size, have been gotten up and stored away in a house, which was destroyed by fire and the mica injured, so that it was never sent to market. None of the localities is near a railroad. A little testing, it can hardly be called mining, has also been done in several places in Clay county, and also in Coosa and Chilton.

Corundum, Asbestos and Soapstone.

These minerals are very commonly associated together and with dikes of basic igneous rocks. The main *corundum* localities are in Tallapoosa county, near Easton postoffice, two or three miles northwest of Dudleyville; and near the river, several miles south of Alexander City. In Coosa county many fine crystals have been obtained from the vicinity of Hanover. While the neighboring rocks in all these localities are *peridotites,* the masses of corundum are mostly found loose in the soil. Very little has been done at any of the localities mentioned towards actual mining, though a fiew shallow pits have been sunk, in some of which the corundum was obtained in small quantity. Dr. Lucas some years ago collected and shipped from Tallapoosa county such fragments and masses of corundum as were to be obtained from surface occurrences and shallow pits.

Asbestos is not uncommon in all the regions which show corundum, but it has not yet been found in quantity or of quality which would make it of commercial value.

Soapstone appears to be much more widely distributed than the other two associated minerals, and it is found in nearly if not all the counties of the metamorphic region. One common occurrence of it in Tallapoosa, Chambers, and Randolph counties particularly, is as a greenish schistose rock, consisting of a felt or mesh of actinolite crystals and soapstone, evidently the result of the alteration of some other rock of igneous origin. This kind of soapstone as it is called, is frequently studded with garnets sometimes half an inch or more in diameter. The rock is split out or sawed out into thin slabs which are used as headstones, hearthstones, and the like. The garnet bearing variety is mottled in a not unpleasing manner with these crystals. Another kind of soapstone is of a grayish brown color and is free from garnets, and has been used in the past by the Indians or former inhabitants of the state in the construction of utensils of various kinds, such as bowls, pots, jars, etc. Fragments of this kind of pottery are to be seen scattered over the fields in dozens of places. A very perfect large bowl of soapstone was dredged out of the Tombigbee river a few miles below Demopolis by Mr. Eli Abbott, and is now in the cabinet of the University of Alabama. On Coon Creek, near the Tallapoosa river, in the county of the same name, there is an old quarry of this rock from which the Indians manufactured their utensils by shaping them out still attached to the parent rock, and when finished, splitting them off. Circular markings on the face of the soapstone mass show still where these finished products were broken away from the solid rock. Almost as a matter of course, this locality is associated with a tradition of an Indian silver mine.

Slabs of soapstone have been used from Chambers county for lining the lime kilns at Chewacla, for the facing of bake-ovens, and for the furnaces used for the concentration of copper ore at Wood's copper mine, the material for the last named use being obtained from the vicinity of the mines.

Lead Ore.

The only occurrence of galena of any consequence thus far known in Alabama, is in the Trenton limestone about five miles west of Jacksonville, in Calhoun county, where much work was done by the Confederate government during the Civil war. Traces of the old quarries are still to be seen, and fairly good specimens of the ore may be picked up around them. With the present perfected machines for concentrating ores it would seem that this deposit might yet be profitably worked, if only the quantity of the ore were sufficient to justify the erection of suitable plant. This can be ascertained only by the expenditure of much money. Very much of the lead ore of Southeastern Missouri is no richer than some which can be obtained from the Calhoun county mines. The subject is well worth testing.

Some small veins with galena have also been observed in the Knox Dolomite.

Loose pieces of pure galena may be found on the surface over the entire state, in localities where it could not possibly be in place. The fact that similar occurrences are noted in all the other states adjacent, has led to the inference that these loose specimens have been dropped by Indians and others who have brought them from Missouri or other lead-producing states. There is not a county in Alabama where there is not a tradition of a "lead mine," said to have been worked by the Indians or early settlers, and the details of these traditions are infinitely varied.

Mineral Paints.

These are mainly the iron ores, the red, brown, and yellow ochres, and barite.

Ochres.—In the soft leached ore beds of the Chilton or Red Mountain formation, there are deposits of soft ore of greasy feel, free from grit, which makes a strong and most durable red paint, extensively used in the Birmingham Paint Works, and shipped from Attalla to Chattanooga to the extent of about 2,000 tons a year.

Some of the argillaceous shales of the limonite banks yield good yellow and red ochres; a fine red ochre of this kind occurring a few miles northeast of Talladega.

In the great clay formation of the state, viz., the Tuscaloosa of the Lower Cretaceous, are numerous deposits of both yellow and red ochres. Some of the yellow ochres have been mined and marketed from Autauga and Elmore counties, and a fine red ochre deposit of the same formation is known near Pearce's Mill, in Marion county. It must be borne in mind, however, that the above mentioned are only a few typical occurrences of these materials, selected out of hundreds that might be mentioned.

Overlying the St. Stephens limestone of the Tertiary, beds of good yellow ochre have been tested in Clarke county, and in the Grand Gulf territory of South Alabama also fine yellow ochre occurs in Barbour and other counties.

Barite.—The usual mode of occurrence of barite or heavy spar, is in boulders or irregular masses imbedded in the residual clays derived from the Trenton limestone, and in loose pieces on the surface. The most important localities are near Tampa, in Calhoun county, near Greensport in St. Clair, near Maguire Shoals on Little Cahaba River, at the "Sinks" on Six Mile Creek, and near Pratt's Ferry in Bibb; in all cases near the contact of the Trenton limestone with the Knox Dolomite.

The Alabama barite is of white, grayish and bluish colors, sometimes stained with iron on the surfaces. In the localities mentioned the barite is very pure and white; but it has not as yet, so far as known, been put upon the market from Alabama.

Tripoli or Polishing Powder.

Tripoli proper, the infusorial or diatomaceous earth or "fossil flour" of organic origin, occurs abundantly in many localities in the lower part of the state, e. g., in the recent swamp deposits near Mobile; in the Second Bottom deposits of the Alabama River at Montgomery; in the Buhrstone and Clayton formations of the Tertiary; the first two being of fresh water origin, while the Tertiary beds, containing marine diatoms and radiolaria, are of marine origin. In view of the fact that this material finds extended use in the covering of steam pipes, etc., it would be well worth while to investigate some of the occurrences more closely. Many details are given in the Report on the Costal Plain of Alabama.

Polishing powder of very different origin occurs in many localities in Northern Alabama. This is the result of the thorough leaching of the cherty limestones and dolomites of the Knox Dolomite of the Silurian, and of the Fort Payne division of the Lower Carboniferous. It is known as "rotten stone," and is a porous rock of finely divided siliceous matter. To fit it for use as a polishing powder it must be crushed, ground and bolted. The largest deposits are in Talladega and Calhoun and Lauderdale counties.

Some shipments have been made from the first named.

Copperas, Alum, and Epsom Salts.

These mineral salts occur in protected or sheltered places where the rocks contain iron pyrites, the weathering of which furnishes the sulphuric acid, and the country rock the iron, alumina, and magnesia. Such occurrences are most numerous in connection with the strata of the Devonian and Carboniferous formations, and are common in the open caves under overhanging rock ledges, known as "rock houses."

In the dark colored sandy clays of the Claiborne and next underlying Tertiary formations, there are pyritous earths which have been put to commercial use in Choctaw, Washington, Clarke, Escambia, and other counties by leaching out the sulphates of iron and alumina and putting them on the market as "mineral extract," "acid iron earth," etc.

At Greenville, in Butler county, a strong solution of these acid sulphates is obtained from a shallow well, and is well known over the state as a medicinal agent.

Nitre.

The limestone caves of the northern part of the state contain large quantities of nitre, which during the civil war was obtained from this source for the manufacture of gunpowder. The marks of the picks then used are still to be seen plainly at some of the localities.

Although an organic substance, the bat guano, so abundant in many of the caves referred to, may be mentioned in this connection. This fertilizer contains 25 per cent. of organic matter, 6 per cent. of nitrogen, mainly in the form of uric acid, and from 1 to 3 per cent. of phosphoric acid, 1 to 3 per cent. of potash, and .6 per cent. of ammonia.

Phosphates.

Silurian Formation.—The phosphates of the Mount Pleasant, Tenn., district extend down into Alabama for two or three miles along Elk River and its western tributaries, Sugar Creek and Little Shoal Creek, into Limestone county. They also show along the state line for several miles to the east of Elk river, extending in places a quarter of a mile or more into Alabama. The geological horizon is probably Trenton, as in Tennessee. The phosphatic rocks do not outcrop over much area since they are usually in comparatively narrow valleys far below the general level of the country, but they underlie some large level tracts and second bottoms of the river and creeks, and are seen also covering hillsides. Exposures of more than 100 acres of these rocks occur along the line of the L. & N. railroad about a mile south of the state line.

There are two varieties to be distinguished, a friable, dark colored, porous, calcareous sandstone, and a light gray, friable, siliceous limestone. The former, derived from a siliceous dark blue limestone, weathering into flags from the fraction of an inch up to eighteen inches in thickness, occupies the lower 6 or 8 feet of the strata. The gray or upper phosphates are from 10 to 25 feet aggregate thickness, though it is not probable that all this thickness of strata is highly phosphatic at any one place. These are derived from a light bluish gray limestone that is often crystalline and that weathers into scales and flags from a fraction of an inch to two or three inches in thickness.

None of these phosphates, so far as they have yet been investigated, comes up to the grade of the Mount Pleasant rock; 75 per cent. of bone phosphate, though it is quite possible that future careful prospecting will discover them in Alabama. Small quantities of the rock have been mined about a mile west of Veto, on the L. & N. railroad.

Some 19 well weathered samples from this part of Alabama have been subjected to analysis with the result that 5 contained from 60 to 70 per cent. of bone phosphate; the others varied from 20 to 50 per cent. with one exception, and this contained less than 13 per cent.

The formations of the Coastal Plain at several horizons, hold beds of phosphatic materials which might well be utilized upon our soils.

Cretaceous Formation.—At the base of the Selma Chalk or Rotten Limestone division of this formation, there is a bed of phosphatic green sand in which occur irregular concretions and nodules of phosphate of lime.

In the disintegration of this bed the nodules of phosphate are left in considerable quantity scattered over the surface and represent in the aggregate, a very great quantity of the material, since the bed extends nearly across the state near or through Eutaw, Greensboro, Marion, Hamburg, Prattville, and Wetumpka. In no place, however, have they been found in sufficient quantity for profitable working.

On the other hand, the phosphatic green sands of this belt and of that next to be mentioned, are of nearly identical quality with the marls of New Jersey, which have been used with such signal benefit upon the soils of that state, and there can be no doubt but that the application of these marls to the soils of Alabama, where such application can be effected without too great cost, would bring about a similar improvement with us.

At the summit of the Selma chalk occurs another bed of phosphatic green sand, with large percentage of carbonate of lime, which outcrops at least half across the state along the southern border of the Chalk, passing near Livingston, Coatopa, Linden, and other points eastward.

A few field tests have been made with both these marls and with most decided good results. We can, however, never expect their use to become general till the railroads are ready to transport them to points within the state at minimum rates.

Tertiary Formation.—Phosphatic nodules are known to occur in several of the divisions of the Tertiary, but in none as yet in quantity to make them of commercial importance. Shell marls, however, are abundant, and of easy access at many points in this region, and have been locally utilized.

Building Stones.

Limestones.—The best of these for building purposes are to be found in the Lower Carboniferous and Trenton formations, and quarries have been opened in Marshall, Colbert, Franklin, Bibb, Shelby, Jefferson, St. Clair, Talladega, Calhoun, DeKalb, and Etowah counties.

The best known are the quarries of T. L. Fossick & Co., at Rockwood, in Franklin county. The equipment at these quarries is very complete and extensive. The stone is from the Lower Carboniferous formation and it has been very largely used in the construction of the locks on the Tennessee River. The LaGarde Lime & Stone Company, at Anniston, have also an extensive plant, using the Trenton limestone, and there are several other quarries of less importance. The Trenton limestone has been used in the construction of the locks at Greensport, and the other sites on the Coosa river.

In the Tertiary formation of South Alabama some of the materials of the Lower Claiborne formation, especially an aluminous sandstone, have been utilized as rough building stones at many points. The St. Stephens limestone also is still more extensively used. This formation holds some beds many feet in thickness, which are called "Chimney rock," from one of the principal uses made of it. This is a soft, somewhat chalky white rock, almost pure carbonate of lime, which is quarried by cross-cut saw, and shaped with saw, hatchet and plane. The principal use to which the blocks are put is the construction of chimneys and fire-places, for which, notwithstanding its composition, it is most admirably adapted, fire-places which have been in use for fifty years being still in a perfect state of preservation. In the region of its occurrence all across the state and also in the adjoining states, nearly all the chimneys and pillars to the houses are constructed of this rock.

Sandstones.—The sandstones of the Coal Measures, the Lower Carboniferous (Hartselle), and the Cambrian (Weisner), have all been used in building, and are well adapted to the purpose. In the Coal Measures quarries have been worked at Jasper and Cullman, and at Tuscaloosa. The locks on the Warrior River at the last named place are constructed of rock obtained from the bed and banks of the river. The Hartselle sandstone is quarried near Cherokee, Colbert county, and the stone has been used in the construction of the locks at the Colbert Shoals on the Tennessee River. The Weisner sandstone has furnished the material for many of the handsome buildings around Anniston.

Granites and Other Igneous Rocks.—While these rocks have not been much quarried in Alabama, they occur in great quantities and in position favorable for quarrying at many points in Lee, Tallapoosa, Chambers, Randolph, Elmore, Chilton, Coosa, Cleburne, and Clay counties. The granites outcrop in "flat rocks," which are low, dome-like masses of naked rock, sometimes 200 acres or more in extent. The largest of these flat rock areas are near Almond postoffice, in Randolph; near Blake's Ferry, and near Rock Mills, and Wedowee, in the same county; also near Milltown, in Chambers; southwest of Roxana, and along Sougahatchee Creek, in Lee. Smaller outcrops are to be found in all the other counties named. With the massive granites are associated the gneisses; both are most excellent building stones, and they are also suitable for monuments. The factories, dams, and bridge piers at Tallassee and vicinity have been constructed of the gneissoid granite, which makes the bed and banks of the Tallapoosa River there. Some use has been made of the granites about Wedowee in Randolph, at

Rockford and other places in Coosa, and rough stone has been used in the construction of the culverts and bridge foundations, etc. of the Central of Georgia Railroad in most of the counties of the metamorphic region traversed by it.

Paving and Curb Stones.—The flaggy sandstones of the Coal Measures and of the Red Mountain formation are very well adapted to these uses, and they can be gotten out in almost any desirable size. In some places these slabs are so uniform and numerous that they have received the name "plank rocks." The flags from the Red Mountain may be seen in the sidewalks and curbs of Birmingham.

Paving blocks are made from the hard flags of the siliceous limestones of the Tennessee Valley and shipped to Memphis.

Slates.

While in many localities in Shelby, Talladega, Calhoun, Cleburne, Clay, Coosa, and Chilton counties, there are great beds of slate which from their surface outcrops appear to be sufficiently promising, yet so far as we have information, they have been put to actual use only during the Civil War and for covering the Confederate arsenal building in Selma.

The slates mentioned belong to several geological formations, viz., The Talladega or Ocoee; the Weisner; and the Montevallo Shales of the Cambrian, and the upper Trenton of the Silurian.

Of these the best are perhaps the slates of the Weisner, occurring in the southwestern part of Talladega county; those of the Montevallo group in Chilton county; on Buxahatchee and Clear Creeks; and those of the Trenton in the "Dark Corner" northeast of Anniston in Calhoun.

Quarries have been started in several localities, but have been carried to no greater depth than 20 to 25 feet, not below the reach of weathering, so that adequate tests have not yet been made.

Sands.

Building sands are obtained from loose beds overlying the formations from which they have been derived; from the drifted sands along water courses; from the stratified sands of some of the newer formations, and from the harder sandstones of the older formations. The best of these sands which have yet come into use are obtained by crushing the friable sandstones of the older formations, especially of the Lower Carboniferous (Oxmoor) division. The material for the glass works at Gate City, analyzing 99 per cent silica—is from this source, the rock being almost at the door of the works.

Sandstones of the Coal Measures and of the Weisner formation are also in places suitable, and in the Tuscaloosa division of the Lower Cretaceous, we also have an unlimited source of sands of every grade.

In the upper of the Cretaceous divisions, viz., the Ripley, there are numerous beds of excellent sands, some quite suitable for glass making e. g. from the vicinity of Linden in Marengo county.

So also in the Tertiary formation we find numerous beds of fine sands, such as occur for instance in the vicinity of Gaston in Sumter county, and further south, in the territory covered by the Grand Gulf formation, are extensive beds of all grades, in Washington, Mobile, Baldwin, Escambia, Covington, Geneva, Dale, Henry, Houston, etc. Travellers in that section do not need to be reminded of the prevalence of sand there. The Lafayette formation lastly, which mantles the entire coastal Plain is prevalently a sand and pebble formation; the sands being as a rule, ferruginous, but in many places quite suitable for building purposes.

Road and Ballast Materials.

The materials used in road making in Alabama are chert, quartz pebbles, and limestone, including dolomite.

The chert has probably been used more extensively than either of the others. It occurs in the Lower Carboniferous formation and in the Knox Dolomite of the Silurian. In the former it is generally in more or less regular beds or sheets, in the latter rather in the form of concretionary masses. The chert from both these sources has found extended use in several counties especially Jefferson, Calhoun, Talladega. That from the Lower Carboniferous formation contains a good proportion of carbonate of lime, and shows a tendency to harden on the surface, thus making an ideal road material. Extensive quarries are near Birmingham, Leeds, Anniston, Jacksonville, and other cities.

The rounded, waterworn *quartz pebbles* are abundant in the Lafayette formation, which is a mantle of sands and pebble covering more or less completely all the central and lower parts of the state. Usually the pebbles are imbedded in a red sandy clay which acts as a cement holding them in place and forming a road surface, scarcely if at all inferior to that made by the chert. In nearly every county of the state from Tuscaloosa to the Gulf, these clay pebble beds of suitable character occur, and there is no reason why any of these counties should lack good roads.

Broken limestone and dolomite, are the most common material in some of the counties of the Tennessee valley, and in parts of the Coosa valley, and the widely distributed limestones of the Lower Carboniferous and Silurian formations of the northern part of the state furnish an inexhaustible supply.

For *ballast*, all the above mentioned road materials have been utilized, and in addition to these broken up sandstones and furnace slags.

Millstones, Grindstones and Whetstnoes.

The conglomerates of several formations of the state, especially of the Weisner Quartzite, the Coal Measures and the Lafayette are capable of yielding good millstones, and locally they have been so used, and in the early days some of them had well established reputations.

For grindstones the sandstones of the Cambrian and of the Red Mountain and Coal Measures formations, have been found suitable, and certain thin laminated sandy shales of the Coal Measuers have served for whetstones of very good quality.

Asphaltum, Maltha, Petroleum, and Natural Gas.

The asphaltum and maltha here referred to are the solid and semi-solid products resulting from the desiccation of the fluid petroleums.

These and petroleum are most common in the Lower Carboniferous rocks of Russellville and Moulton valleys and of the southern slopes of the Little Mountain of the Tennessee valley region. They occur in the highly fossiliferous crinoidal limestones and the course-grained sandstones of the formation, which are often saturated with them to the extent that they ignite when thrown into the fire. On the surfaces of these rocks the petroleum may often be seen in yellow drops, but generally these surfaces are black from the maltha or "tar," which on sufficient exposure hardens and oxidizes into asphaltum. Several car loads of the black bituminous sandstone from the top of the Little Mountain south of Leighton, were shipped to Memphis and the tar or asphalt there extracted. These substances were also extracted from the crinoidal limestones by boiling, and several barrels of the tarry matters were scooped up out of a drift.

These tar springs have been known for many years and they were formerly places of resort by the afflicted who drank the tarry water or took pills of the maltha.

Petroleum can be obtained from the same bituminous sandstones and limestones, and also from the Black Shale of the Devonian formation, which is usually sufficiently saturated with bituminous matter to burn or ignite when thrown into the fire.

Natural gas is quite common in many parts of the state, occurring as a rule along with salt water, sometimes with small quantities of petroleum accompanying, oftener without it.

Probably the most promising of the borings for petroleum are those put down in the Tennessee Valley region. The Goyer well No. 1 in the Moulton Valley, is said to have had at one time a capacity of 20,000 cubic feet of gas and 25 barrels of oil a day; the oil was of dark green color with a not unpleasant odor. This well was bored to a depth of 2,120 feet.

For some reason the oil flow was lost, and never recovered in paying quantity. Many other deep wells have been bored in different parts of the state, as well as in the Tennessee Valley region, but without success, so far as petroleum in commercial quantity is concerned.

Many of these borings have been made in the Southern part of the state, especially in Clarke, Washington, and Mobile counties, where there are so many salt wells and salt seeps. Salt water and natural gas in considerable quantity have been obtained from many of these wells, but as yet no petroleum in commercial quantity. At Cullom Springs in Choctaw county near Bladon, a deep well bored about 1886 was probably the first among the recent borings to show considerable amount of natural gas, but many of the old borings in the salt region made during and before the Civil War, yielded along with the brine, large quantities of this gas. In places the gas and salt water rise to the surface in natural seeps.

Perhaps the most abundant supply of natural gas along with salt water comes from the wells lately sunk near the Bascomb race track in Mobile. Recent measurements of the flow of gas of these two wells, have shown it to be 35,000 cubic feet daily for each. As the water gushes from a four inch pipe to the height of six or seven feet it is such a foam of water and gas that it may be ignited and will frequently burn for several minutes till splashed out by chance fall of the water.

The salt wells of Clarke and Washington counties were of great value to the state during the war as source of that indispensable and at the time scarce substance, common salt.

Mineral Waters.

It would be impossible to enumerate all the mineral wells and springs of the state, even those which have a more than local reputation. They are to be found in all parts of the state and show great variety in quality. The following springs and wells either ship water to all parts of the state and outside of the state, or are places of resort with accommodations for visitors: Bailey Springs in Lauderdale County; Chocco Springs, Talladega county; Chandler's and Chambers' Springs also in Talladega; Piedmont Springs in Calhoun; Mentone Springs in DeKalb; all these have waters that are chalybeate or alkaline carbonate. Woolley or Millhouse Spring in Limestone; Johnson well in Madison; White Sulphur Springs in DeKalb; Blount Springs in Blount; St. Clair Springs in St. Clair; Shelby and Talladega Springs in the counties of the same names are all strong sulphur waters. Cullom and Bladon Springs in Choctaw county, were well known places of resort in former years, still much visited on account of their fine sulphur and vichy and other waters. The sulphur well at Jackson, Clarke county, gives a mild saline sulphur water which is not exceeded in palatability by any, unless it be that of a sulphur spring at the Lower Salt works near Oven Bluff.

Many of the artesian borings in the central and lower parts of the state give waters which are much used and which are sent to all the markets of the state. Livingston in Sumter county is perhaps the best known of these. In the Flatwoods belt on the border of the Cretaceous and Tertiary formations, in Sumter county there are several shallow wells which yield strong *epsom salts* waters that have a wide reputation and are now extensively bottled and shipped. Of the same nature is the water from the Gary Spring near Centerville, in Bibb county, with a composition very nearly identical with that of the celebrated Tate Springs

The Ingram Lithia springs, Cook's Springs and others, have also wide reputation.

The Geological Survey of Alabama is now engaged upon a systematic investigation of the natural waters of the state and many chemical analyses are now available, though not yet published.

Note on Stone Quarries.

In addition to the quarries supplying cut stone for building purposes, mention may be made of quarries supplying rough stone only, viz.:

The *Killebrew Quarries,* two and a half miles east of Berry, Fayette county, on the Southern Railway, supply rough stone for the improvement of the Mississippi River; about 20,000 to 30,000 tons per annum. This quarry is equipped with crushers, and furnish broken stone suitable for ballast.

Messrs. Christie and Lowe, Ledule, Fayette county, also on the Southern Railway, are quarrying the same rock as the Killebrew, viz., sandstone of the Coal Measures, to be used on the jetties of the S. W. Pass, La. This quarry, opened in 1903, has shipped 50,000 tons of stone up to May 15, 1904.

SOILS.

It would be obviously out of place in a document like the present to attempt to give an account of the many soil varieties of the state and their adaptation to various crops. This subject has been treated somewhat in detail in our Agricultural Report, 1881-2.

But inasmuch as the soils constitute the most recent of our geological formations, they must be included among our mineral resources, and certainly no one of these mineral resources can be compared with them in importance and interest to every citizen of the state.

A general discussion of the soils, from the point of view of their geological relations seems, therefore, to be called for here.

Since the soils have been derived from the disintegration and decay of the older rocks, a geological map might, to a certain extent, serve also as a soil map, but these products of decomposition now rarely rest upon the parent rock, but have been removed more or less remotely from their place of origin, and after various admixtures have been redeposited upon foreign terranes with which they have no connection; again, many of the parent rocks of now existing soils have themselves in their turn been soils derived from still older rocks, have been deposited as sediments, compacted, elevated and again disintegrated and decomposed into soils. These are some of the difficulties which we meet with when we attempt to trace a soil back to its origin.

Another difficulty comes from the fact that soils from various sources have often very similar composition, for all soils are essentially the insoluble residues left from the weathering of older rocks, and these insoluble residues, from whatever parent rock derived, are mixtures in varying proportions of sand and clay, with small amounts of the soluble salts derived from these rocks and not yet completely leached out of the resulting soils. It follows, therefore, that soils from whatever source derived, will differ from each other *mainly* in the relative proportions of the sandy or siliceous and the clayey constituents.

It should be borne in mind, further, that in consequence of the highly absorptive and retentive qualities of clay, the relative proportions of lime and of the elements of plant food in the soils, such as potash, phosphates and the like, will in great measure depend upon the amount of the clayey constituent, so that the classification of soils into *sandy* and *clayey* carries with it far more than this primary distinction.

As a broad generalization, it may be said that residual soils, *i. e.*, those which have not been far removed from the parent rock, exhibit the widest variations, while the transported or drifted soils are more uniform in composition. And furthermore, the greater the distance the transported soils have been carried from their place of origin, and the oftener they have been taken up and redeposited, the more complete is the separation of the clayey constituents from the sand, and the more complete is the leaching out of the soluble salts upon which in great measure the fertility is dependent. All this is illustrated in the changes to be observed in the soils as one goes from inland towards the coast.

For convenience in the discussion of its soils, the state may be divided into two parts, approximately coextensive with the Mineral District and the Agricultural District, respectively.

In the first, the soils are in the main, *residual*, *i. e.*, they have been derived from the rocks upon which they now rest, and show, therefore, more or less close relationship to them. In the second, the Coastal Plain or Agricultural District, the Cretaceous and Tertiary formations have been overspread with a mantle of sandy loam and pebbles, *transported* from elsewhere, and the soils are in great measure made from these materials, modified, however, locally by admixtures with the disintegration and decomposition products of the underlying older rocks.

The Mineral District.

As before stated, the soils of the Mineral District are mostly residual in their nature, and while the parent rocks are sandstones, shales, and limestones, each of these is varied by admixtures with the others, and to such a degree as to give rise to a great variety in the resulting soils. The three principal varieties are here given, but it will be understood that these regions, and admixtures of the red loams of this mantle with the native marly soils, give rise to many varieties, such as the *Red Post Oak soils,* the *Piney Woods Prairie soils,* etc.

Another departure from the prevailing Coastal Plain sandy loams is caused by the great clay formation of the Lower Tertiary, which gives origin to the *Post Oak Flatwoods* of Sumter and Marengo counties. East of the Alabama River in Wilcox and Butler counties, these clays hold much lime and form regular "prairie" soils, characteristically developed along Prairie Creek in Wilcox.

Besides the above, there are small areas of marly soils in the Tertiary, due to the shell beds which occur at intervals in the lower or lignitic division of this formation. Of this kind are the celebrated Flat Creek lands of Wilcox, marled by the outcrop of the Woods Bluff greensand shell bed, which is also responsible for fertile lands on Beaver Creek, the same county, on west side of the river, and on Bashi Creek in Clarke county.

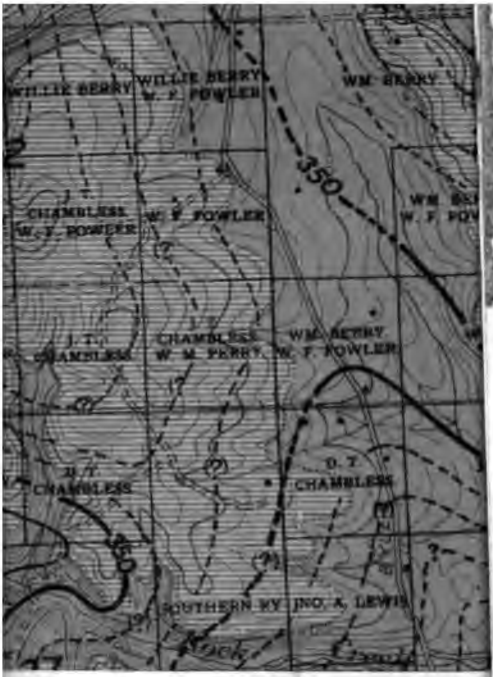
The Nanafalia shell bed or marl also is responsible for many tracts of fertile limy soils in Marengo and Wilcox.

In the lower counties of the state the materials of the Lafayette are in general more sandy than is the case further north, and we find in this section also another surface mantle, viz,. the Grand Gulf, underlying the Lafayette, and like it consisting mainly of sands with some beds of laminated clay intercalated.

By reason of this double mantle the thickness of the sandy surface beds is much increased, so that the Miocene limestones, which are known to underlie this section, seldom if ever come to the outcrop and influence the soils except along the immediate banks of the Chattahoochee and possibly of some of the smaller streams. In all this region which is gently rolling or nearly flat, shallow ponds, pine barren swamps, and open savannahs are characteristic of the landscape, due, so far as we can make out, to the uneven surface of the Grand Gulf clays which underlie the Lafayette sands at shallow depths These beautifully situated, high, level lands are characteristic of parts of Baldwin and Mobile counties, and are destined to become valuable farming lands when lumbering and turpentining shall cease to give chief occupation to the population, and this, from present prospects, will soon happen since the pine has been cut off or destroyed by fire over very much of the territory.

Bottom Soils. Along all the larger streams of the Coastal Plain region we find developed normally three well defined terraces. The ***first terrace*** or bottom is subject to overflow and its soils are the sands and other materials periodically deposited by the stream, and are the most recent perhaps of the formations. A few feet above the high water mark and consequently not subject to overflow except in the depressions caused by erosion, are the ***second bottoms,*** with very characteristic soils, yellowish silty loams increasing in sandiness from above downwards. The second bottoms are on an average perhaps a mile in width, and are always choice farming lands. Upon this terrace are many of the great plantations of ante bellum days.

About 100 feet above the second bottom we find a ***third terrace*** averaging some three miles in width, the soils of which are of the usual Lafayette type, red sandy loam underlaid by pebbles. On this terrace are situated most of the river towns such as Tuscaloosa, Selma, Cahaba, Claiborne, St. Stephens, Jackson, Columbia, etc. The soils on this terrace are not essentially different from the Lafayette soils elsewhere, unless possibly they are a trifle more sandy. Above this third terrace at varying elevations are the broad level uplands making the interstream country of the Coastal Plain, and it is upon these uplands that we find the most characteristic and widely distributed of the soils of this region based upon the red sandy loam of the Lafayette.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GEOLOGICAL SURVEY OF ALABAMA

EUGENE ALLEN SMITH, PH. D.
State Geologist

BULLETIN No. 10

RECONNOISSANCE REPORT
ON THE
FAYETTE GAS FIELD
ALABAMA

BY
M. J. MUNN
Geologist, U. S. Geological Survey

Prepared in co-operation with the United States Geological Survey.

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1911.

LETTER OF TRANSMITTAL.

To His Excellency,
EMMET O'NEAL,
Governor of Alabama.

Sir:

I have the honor to transmit herewith, the manuscript of a Reconnoissance Report on the Fayette Gas Field by M. J. Munn, Geologist, U. S. Geological Survey, with the recommendation that it be printed as Bulletin No. 10 of the Alabama Geological Survey.

Very respectfully,
EUGENE A. SMITH,
State Geologist.

University of Alabama,
July 10, 1911.

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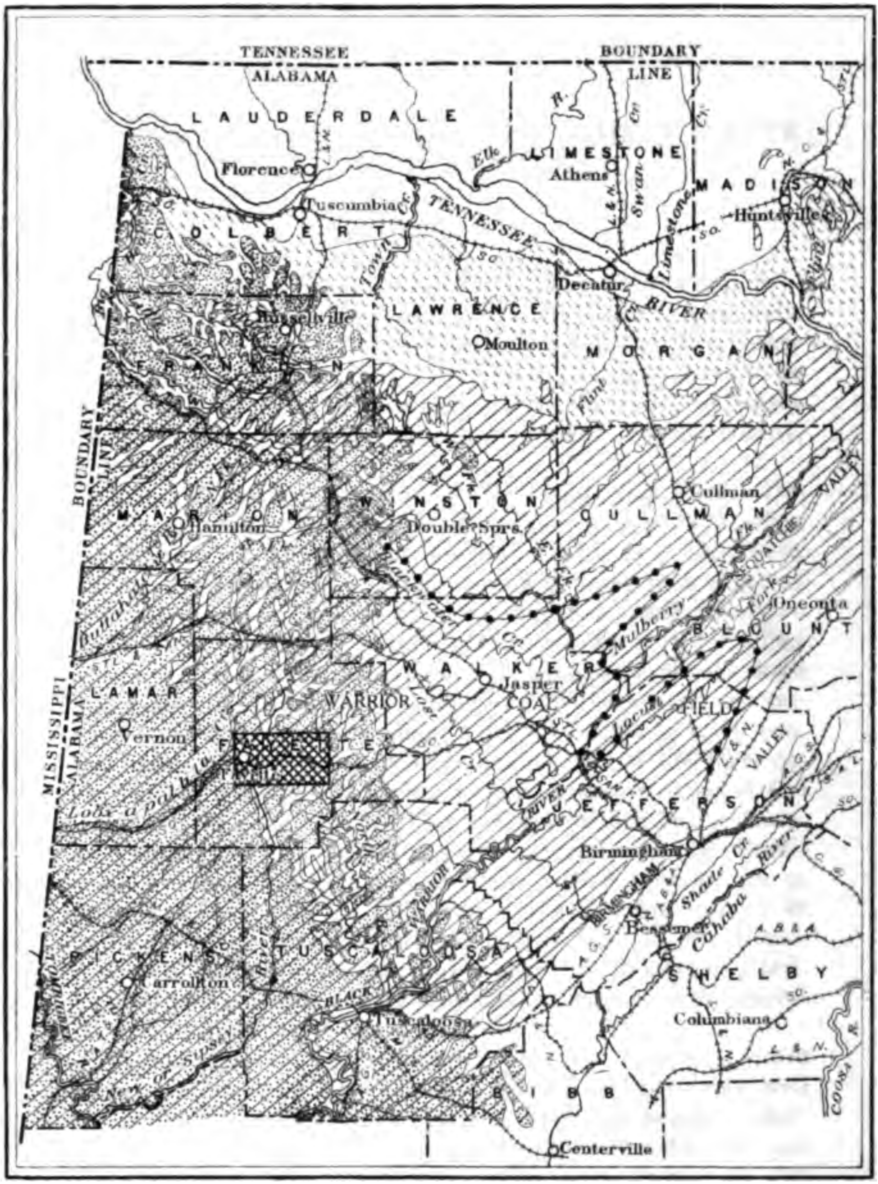

SKETCH MAP OF NORTHWESTERN ALABAMA

Showing location of area mapped in the Fayette Gas Field, the general structure of the region and the northern and eastern extent of the Pennsylvanian Series of rocks in which the gas is found.

Scale 1 inch = 25 Miles

0 25 50 75

LEGEND

▨	▨	▒	▩
Cretaceous and younger beds overlying Carboniferous rocks of both the Pennsylvanian and the Mississippian Series.	Rocks of the Pennsylvanian Series (Coal measures) and approximate outcrop of the Black Creek coal	Rocks of the Mississippian Series, including Pennington Shale, Bangor Limestone and Hartselle Sandstone member	Area mapped in the Fayette Gas Field.

RECONNOISSANCE REPORT ON THE FAYETTE GAS FIELD, ALABAMA.

INTRODUCTION.

Location of the Fayette Gas Field.—The Fayette gas field as developed on February 1, 1911, consists of three deep wells in which gas occurs in commercial quantities and three other wells that, having furnished considerable gas, may prove to be profitable. All these wells are situated in the valley of Sipsey River, about 2 miles east-southeast of Fayette, Fayette county, Alabama.

Discovery and Development of the Fayette Gas Field. Development work in this vicinity was begun early in 1909, when a diamond drill hole was put down at what is now Gas Wells station in search for coal. This hole was bored to a depth of 475 feet encountering two or more sandstones that furnished small quantities of oil. These indications led to the drilling of two deep test wells, for oil and gas, adjacent to the diamond drill hole. On December 20, 1909, one of these wells encountered a gas-bearing sandstone at a depth of 1,400 to 1,420 feet, and began producing gas at an estimated rate of 1,600,000 cubic feet per day, the gas having a closed pressure of about 630 pounds to the square inch. This well was drilled by the Eureka Company which was afterwards merged with the Providence Oil and Gas Company, and the well is now known as Providence well No. 1. The other test well, located about 30 yards from the Diamond drill hole, was sunk by the Providence Oil and Gas Company to a depth of about 1,685 feet. In it oil and gas were reported in small quantities from several horizons, but the well was a failure.

Shortly after the completion of well No. 1, several other wells were started. One of these, known as Providence well No. 8, reached the gas sand March 1, 1910, and began producing at a rate estimated to be about 4,500,000 cubic feet per day. This is said to be the best well in the field. Providence well No. 6 was completed about April 15, 1910, finding gas in paying quantities. The initial capacity and the closed pressure of this well are not known to the writer. Its daily capacity has been estimated at between 2 and 3 million cubic feet and the present (Dec. 1, 1910) closed pressure is said to be about 580 pounds. Providence well No. 3, located about a half mile from the railway station at Fayette, was completed in April, 1910, to a depth of about 2,200 feet. Aside from several "shows" of oil and gas this well is reported to have furnished an initial flow of about 150,000 cubic feet of gas from a depth of about 1,400 feet. The well was abandoned. Providence well No. 9 was completed about June 1, 1910, with a reported daily capacity of about 800,000 cubic feet. This well is said to have furnished salt water from the gas-bearing sand, as does Providence well No. 10, which was drilled later. The latter is said to have furnished a strong flow of gas until shot with 80 quarts of nitroglycerine after which the salt water increased so much in quantity and head as to greatly reduce the capacity. Four wells within a few thousand feet of the center of the gas field, and six others at distances of 1 to 20 miles from it, had been drilled to various depths, or were being drilled at the time of the writer's last visit, Dec. 8, 1910. At that time none of these were producing oil or gas in commercial quantities.

Purpose and Scope of this Report.—This report and its accompanying maps are the result of a co-operative agreement between the Alabama Geological Survey and the United States Geological Survey, by which each organization contributed funds for field work, and the Alabama Survey met the expense of publication.

The chief objects of this work were first to prepare a good topographic base map suitable for use of both the geologist and the oil producer; and, second, to make a preliminary study of the geologic structure of the rocks of the gas field and vicinity for the purpose of determining as far as possible the nature and extent of the folds in the strata and to see if geological work of value to the oil and gas producers could be done in advance of the drill.

The geologic work was entirely of a reconnoissance nature, and, owing to the limited funds available, it was confined principally to an attempt to locate the larger folds and other structural features by spirit level lines along the outcrops of recognizable beds. The writer did not attempt while in the field to correlate the outcropping rocks of this region with those of better known localities to the east, and the broad tentative correlations that have been made in this report are based largely upon the evidence published in previous reports and that furnished through the courtesy of other geologists who have studied portions of the region.

Field work for the topographic map was done between October 1, 1910, and February, 1911, by Mr. R. H. Reineck, assisted by Mr. J. M. Rawls, both of the U. S. Geological Survey.

Methods employed in field work.—As a base for the vertical control of the topographic map the top of the north rail at the railroad crossing in front of the station at Fayette was calculated from railroad levels to have an elevation of 359 feet above mean low tide. From this bench mark, level lines were run by planetable and telescopic alidade to every part of the area mapped. The mapping was of a somewhat detailed reconnoissance nature, consisting of flying level lines and stadia traverse over nearly all of the roads, and tape traverse and barometer elevations through the wooded area between the roads. No astronomical observations were made for latitude and longitude, the traverse lines being adjusted upon closed circuits. The section and township lines were determined by locating some of the section corners on the map and platting the unlocated ones from distances given for each line from notes obtained from the General Land Office. The farm lines were compiled from the county records by Mr. E. C. Janney, attorney, Birmingham, Alabama, who kindly furnished these data at a nominal charge.

Geologic work was begun by the writer October 9, 1910, and was discontinued for want of funds December 9. The lack of a suitable base map at the beginning of the work necessitated the running of stadia traverse and level lines by the writer over much of the eastern quarter of the work. These traverse and level lines were carried over most of the roads and to all points in the interior where favorable rock exposures were to be found. The dip of exposed beds was determined principally by level lines along their outcrops. The traverse and level lines and such topographic sketching as was done in connection with the geologic work were later used for the topographic base map.

Acknowledgments.—The field work upon which this report is based was done under the general direction of Dr. Eugene A.

Smith, State Geologist of Alabama, and Mr. David White, U. S. Geological Survey, to whom the writer is indebted for many suggestions. To Mr. Charles Butts, U. S. Geological Survey, and Dr. William F. Prouty, of the University of Alabama, he is also indebted for data used in the tentative correlation of the rocks of this region. Maps and field notes made by Dr. Prouty in this district were consulted during the progress of the work, especially in the interpretation of geologic structure. The writer is also indebted to Mr. S. A. Hobson, geologist, for the detailed logs of the wells of the Providence Oil and Gas Company; to Mr. F. Harley Davis, President of the Davis Drill Co., for a core drill record of Cosmos well No. 1, and for courtesies shown the writer and his assistants in the field; to Prof. W. O. Crosby, of the Massachusetts Institute of Technology, for his classification of the rocks in the core of the Cosmos well; to Mr. H. G. May, Superintendent Alabama Central Oil and Gas Company; to Mr. W. W. Silk, Fiscal Agent, Five Rivers Oil and Gas Company; Mr. J. F. Moore, the Minge Mortgage and Realty Co., Birmingham, Alabama, and others for records of wells, and to many citizens of the town of Fayette and the surrounding country for their uniformly courteous and considerate assistance.

GEOLOGY.

General Statement.

The Fayette gas field is situated in the western part of the Warrior coal field. The country is one of relatively low relief and the larger streams are sluggish, meandering across broad alluvium covered valleys. The hills which arise from 100 to 200 feet above the principal streams are deeply dissected.

The outcropping rocks in the northeastern part of the Warrior coal field belong to the Pennsylvanian series ("Coal Measures") and are of Pottsville age. In the western and southwestern part, adjacent to the Fayette gas field, these beds are mantled by a series of unconsolidated sand, gravel, and clay of Cretaceous and younger age which rest unconformably upon the coal-bearing rocks. The northeastern extent of the Cretaceous beds marks approximately the shore line of a great arm of the Cretaceous sea which covered a large portion of what is now the Atlantic and Gulf Coastal Plain. Over the Warrior coal field these unconsolidated beds are thinnest along their northeastern border. The plane of contact between the Carboniferous and overlying Cretaceous beds dips southwest at a low angle and the latter become correspondingly thicker in that direction. The southwest extent of the coal-bearing rocks in the Warrior field is unknown, since the plane of contact between them and the Cretaceous lies far below the deepest valleys in Western Alabama and in Mississippi, and very few deep wells have been drilled to it, but inasmuch as most of the series is present at the Cretaceous margin at Fayette, it is highly probable that the "Coal Measure" rocks extend far to the southwest under the Cretaceous and Tertiary rocks of the Coastal Plain.

The Fayette gas field is located at a point where the plane of contact between the Carboniferous and Cretaceous rocks is at or just below the valleys of the streams, the Carboniferous beds being exposed at rare intervals in narrow strips along the base of the valley walls, the loose Cretaceous rocks covering the hills to a maximum depth of 200 or 300 feet. Since no oil or gas has yet been found in the Cretaceous beds of the Warrior field, no detailed attention need be given to them. From the data in hand, it seems almost certain that the sandstone furnishing the large flows of gas at Fayette belongs to the lower portion of the Pennsylvanian series, and it is therefore important in this report to give more attention to the general distribution of this and the underlying formations which may contain valuable accumulations of oil and gas at favorable places within the Warrior field.

STRATIGRAPHY.

GENERAL STRATIGRAPHY OF THE WARRIOR COAL FIELD.

Our knowledge of the stratigraphy and structure of the greater part of the Warrior coal basin in Alabama rests upon the most excellent reports by Henry McCalley, whose last great work was the "Report on the Warrior Coal Basin," published by the Geological Survey of Alabama* in 1910.

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*See also a report on the Geology of the Warrior Coal Field published by the Geological Survey of Alabama in 1886.

Although the field examinations by Mr. McCalley were made without the aid of topographic base maps, and with limited facilities for precise work, his large map, which extends to the Fayette district, has, so far as tested by later and more detailed observations, revealed a high degree of accuracy and value, and it long will continue the best and most reliable source of information regarding the greater part of the region. The subdivisions of the coal measures given in McCalley's text and map have been adopted by Butts in the Birmingham folio and are employed in the present report.

The rocks not exposed at the surface in the Fayette gas field have been studied to a limited extent in well sections to a maximum depth of about 2,350 feet, below which no well has yet penetrated. The possibility of there being lower strata favorable in composition and character for accumulations of oil and gas is of importance to those interested in the development of the field.

The nearest exposures of formations underlying the Pennsylvanian series are along Birmingham and Sequatchie valleys to the east and northeast. On the western side of Birmingham valley the rocks have been upturned and faulted in such manner as to expose thousands of feet of strata which extend westward under the "Coal Measures" to an unknown distance. (See generalized sections, Pl. II, in pocket). These exposures furnish the best means of determining in advance of very deep drilling the nature of the formations lying below the bottom of the deepest well in the Fayette district and therefore will be briefly discussed below.

ROCKS EXPOSED ALONG THE EASTERN BORDER OF THE WARRIOR COAL FIELDS.

PRE-CARBONIFEROUS ROCKS.*

The oldest and stratigraphically the lowest beds exposed along Birmingham valley consist of 1,000 to possibly 1,500 feet of thin-bedded blue limestone interbedded with gray or yellow shale, of Cambrian age. Above them are about 3,300 feet of Knox dolomite, which comprises about 600 feet of thick-bedded, non-cherty, gray, crystalline dolomite at the base, (Ketona dolomite member) overlain by as much as 2,800 feet of thick-bedded crystalline dolomite with chert in beds, nodules, and stringers.

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*The data contained under this heading are taken very largely from chapters by Chas. Butts in Bull. 400, U. S. Geol. Survey.

Unconformably upon the Knox dolomite is a dove-colored to blue, generally thin-bedded, limestone, from 300 to 500 feet thick, of Ordovician age, which, in previous reports of the Geological Survey of Alabama has been called the Pelham limestone, and which is called Chickamauga limestone by the U. S. Geological Survey.

The Silurian rocks of this region are represented by the Clinton ("Rockwood") formation which overlies the Pelham or Chickamauga limestone unconformably. It is composed of varying amounts of gray and yellow shale; green, brown and red sandstone, and beds of limy red iron ore with a total thickness of 200 to 500 feet.

The Devonian system, which is thousands of feet thick in the northern Appalachians, in this region is generally represented by only a few feet of black Chattanooga shale. In places the Devonian rocks also include the Frog Mountain sandstone, which is 20 feet or less in thickness and underlies the Chattanooga shale. Over a large portion of Alabama, Tennessee, and Kentucky the Chattanooga shale is less than 30 feet and rarely exceeding 100 feet in thickness. At almost every point where it outcrops or has been pierced by wells this black shale has been found to be more or less petroliferous, but in a very few places is the oil and gas to be found in paying quantities. East and north of the Warrior coal field the Devonian rocks lie unconformably upon the Clinton formation and also are separated by an unconformity from the Carboniferous system above.

CARBONIFEROUS ROCKS.

The Carboniferous rocks exposed in Sequatchie and Birmingham valleys are several thousand feet in thickness. These are separated in two great series; the Mississippian series below and the Pennsylvanian series above. Since all of these rocks are probably within reach of the drill in the Fayette gas field, they will receive more attention in this report than the underlying formations which have been described above.

MISSISSIPPIAN SERIES.

Note—In order that the relations of the formation names of the Mississippian series used in this report, to the names heretofore in use in the reports of the Alabama Geological Survey may be clearly understood, the following note is deemed necessary. To the northward of Birmingham the strata of the Subcarboniferous or Mississippian series, between the Fort Payne chert below and the base of the Coal Measures above—prevalently limestone but with subordinated shales and sandstones,—have received the name Bangor. A somewhat persistent bed of sandstone, accompanied with some shale, separating two great bodies of limestone of this formation, has been called the Hartselle sandstone. These limestones, sandstones and shales in the geological position indicated, constitute the Bangor phase of the Mississippian or Subcarboniferous as used by the Alabama Geological Survey, since 1891.

To the southward of Birmingham the strata occupying the same geological position, namely, between the Ft. Payne chert below and the base of the Coal Measures above—prevalently shales and sandstones with subordinated beds of limestone—have received the name Oxmoor. The Oxmoor of the south and the Bangor of the north have been deemed by the Alabama Survey as equivalents in time but with lithological variations due to geographic positions.

The name Oxmoor should be retained in the Alabama reports as a formation name, since it has priority, and it should be well understood that it includes the Floyd, Pennington and Parkwood of the U. S. Geological Survey authors, in so far at least, as the Parkwood is of Mississippian and not Pennsylvanian age. The only objection made to the use of the term Oxmoor comes from the fact that some of the authors of the U. S. Geological Survey have used it in a restricted sense to designate a particular bed of sandstone which they have placed below the Bangor and above the Floyd, while as a matter of fact the Bangor is a formation contemporaneous with the Oxmoor but in a different locality and with correspondingly different lithological character. The Floyd is merely a synonym of part of the Oxmoor.

No doubt some of the limestones in the Oxmoor area may be found to be actually continuous with some of the great limestone beds of the Bangor area, but it will not do to place the Bangor at the top of the series with the Oxmoor sandstone next below it and the Floyd shale below the Oxmoor as has been done by one of the writers, nor to place the Bangor in the lower part of the Floyd and ignore the term Oxmoor altogether, as has been done by another writer, especially when the use of the term Oxmoor by a writer of the U. S. Geological Survey, in a different sense from that in which it is used by the members of the Alabama Geological Survey, is made the reason for discarding the term Oxmoor. On this principle it would be possible to throw out any well established name.

To designate somewhat clearly defined lithological variations in the strata of the Mississippian series between Ft. Payne chert and Coal Measures in certain localities, as for instance in Shades Valley southward of Birmingham, the terms Parkwood, Pennington and Floyd might be used with advantage and no objection is made to their use if it be understood clearly that they together make up the Oxmoor formation of that section, in the sense in which that term has been consistently used in the Alabama reports.—E. A. S.

In this region the Mississippian series is separated into four formations, which, in ascending order are: Fort Payne chert, Bangor limestone (including the Hartselle sandstone member), Pennington shale, and Parkwood formation. So far as known all the Parkwood and part of the Pennington are wanting in the Warrior field, so that there is an unconformity between the Mississippian and Pennsylvanian series in that area, the base of the Pennsylvanian series lying upon Pennington shale at a horizon near its bottom.

Fort Payne chert.—The Fort Payne chert, which includes the Tuscumbia limestone and Lauderdale chert of previous Alabama State Survey reports, consists of 125 to 250 feet of yellowish chert in thin layers ranging from a few inches to two feet in thickness. This chert is very hard and brittle, and, where unexposed to weathering and but slightly fractured by deformation, it will probably prove to be a zone of hard drilling, the great hardness of the material wearing the bits rapidly. This is a very persistent formation and most probably extends throughout the Fayette gas field. Because of its whitish color in drillings and its hardness, it may be mistaken by drillers for a sandstone, but its association with the soft black petroliferous Chattanooga shale below should render it recognizable by drillers.

Bangor limestone.—The formation known as the Bangor limestone has an average thickness of about 700 feet. It is composed predominantly of limestone, but also contains much shale and sandstone. The limestone is generally light gray in color, very pure, crystalline, and thick-bedded. In places thin beds of red or gray shales and clay occur near the top. The limestone of this formation is separated into two well marked divisions by a very persistent sandstone about 100 feet thick, which occurs about 200 feet above the base of the formation. This bed, known as the Hartselle sandstone member, varies from fine-grained and hard, to coarse and friable, and in places contains a thin layer of fine conglomerate. Along Birmingham valley north of the vicinity of Birmingham, and in Sequatchie Valley, the Bangor limestone has the general character named above. South of Birmingham the limestone phase disappears and the formation is principally shale with the Hartselle sandstone member growing thinner toward the south. The Bangor limestone and the Pennington shale are equivalent to the Floyd shale south of the latitude of Birmingham. Studies by Charles Butts* have revealed other variations in the Mississippian series from north to south along Birmingham Valley, which will be briefly discussed later.

Pennington shale.—In Murphrees Valley, and along the western side of Birmingham Valley, and where it comes to the surface along the Sequatchie anticline in Blount county, the Pennington shale consists of 50 to 100 feet of gray shale, locally containing thin layers of red and green shales and a little chert. East of Birmingham in Shades Valley the Pennington is about 300 feet thick and consists of dark red, black and gray shales, a little chert, some pink shaly sandstone, and some fine conglomerate. South of Birmingham, on the western side of the valley, the Pennington shale and Bangor limestone pass into the Floyd shale.

Floyd shale.—As stated above, the Floyd shale occurs south of Birmingham on both sides of Birmingham Valley at least to the place where the Mississippian rocks pass beneath the Cretaceous sand and gravel. It was deposited contemporaneously with the Bangor limestone and Pennington shale north and northwest of Birmingham. The Floyd is largely shale, gray, black, or pink in color. It contains some fine-grained sandstone, a few thin layers of limestone, and a little fine conglomerate. The Hartselle sandstone member passes unchanged from the Bangor limestone at the northeast into the Floyd shale at the southwest and is present wherever the Floyd comes to the surface on the western side of the valley southwest of Birmingham. Southward from Bessemer on the southeast side of the valley this sandstone member disappears. The Floyd has a thickness of 1,000 to probably 1,200 feet. Attention is called to the probable character of this portion of the Mississippian series in the vicinity of the Fayette gas field. From the data now available, it seems probable that the belt of transition from Pennington shale and Bangor limestone to Floyd shale may pass westward from the vicinity of Birmingham in the general direction of the Fayette gas field. For this reason there is some uncertainty as to whether the Pennington shale and Bangor limestone, or their equivalent, the Floyd shale, are present there. The probable depth at which these rocks will be encountered at Fayette is discussed under the heading "Unexposed Rocks in the Fayette District."

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*Bull. 400, U. S. Geol. Survey, pp. 18-20, and U. S. Geologic Atlas, folio No. 175, Birmingham quadrangle.

Parkwood formation.—In Shades Valley, east of Birmingham, the Pennington shale is overlain conformably by the Parkwood formation consisting of 2,000 feet of sandstone and shale. Sandy shale, either green or gray, predominates in this formation. Thin-bedded sandstones up to 100 feet in total thickness are common. Unlike the other lower Mississippian rocks, the Parkwood contains no limestone, and is practically destitute of fossils. This formation is present north and east of Birmingham but absent along the whole length of the western side of Birmingham Valley and also in Sequatchie Valley, and it seems probable that it is also wanting throughout the Warrior field, including the Fayette district. In this region there is a stratigraphic hiatus or unconformity of possibly 2,000-3,000 feet between the Mississippian series ("Sub-Carboniferous") and the Pennsylvanian series (Upper Carboniferous or "Coal Measures").

PENNSYLVANIAN SERIES.

Pottsville formation.—Overlying the Mississippian series along the Birmingham and Sequatchie valleys there are about 2,600 feet of Pottsville shale, sandstone, clay, and coal. East and southeast of Birmingham in the Cahaba and Coosa coal fields the Pottsville strata are much thicker, reaching a maximum of about 7,000 feet. The base of this formation is exposed on both sides of Birmingham Valley and along the northeastern and northern border of the Warrior coal field. Rocks of Pottsville age form the surface of the coal field southwest to where this formation disappears beneath the Cretaceous sand and gravel in the vicinity of Fayette.

Though incomplete sections of Pottsville rocks have been studied by geologists in various parts of the Warrior coal field, there is little information available to show whether the whole formation tends to thicken or to thin, from the eastern and northern edges of the basin toward the Fayette gas field. The Pottsville beds thicken from north to south along their exposures at the eastern margin of the Warrior coal field, and they appear to thin somewhat along the northern margin from east to west. The effect of these two opposing tendencies upon the thickness of this formation in the Fayette district could be determined only by a careful correlation of the coal beds across this territory and a study of fossils from deep core drill holes in the Fayette district. The evidence collected to date suggests a slight thinning of the Pottsville in that region.

In the Birmingham region the lower third of the Pottsville formation carries thick strata of siliceous sandstone known as "millstone grit"; in the middle third sandy shale predominates; while the upper third is marked by a considerable proportion of sandstone of a feldspathic type rather than of the siliceous type characterizing the lower third. All of the coal beds of the Alabama fields occur in this formation. Though more or less coal is found throughout the formation, the thickest and most valuable beds are in the upper two-thirds.

Near the base of the Pottsville formation, east of Birmingham Valley, are two very persistent sandstones, the Shades sandstone member below and the Pine sandstone member above. Each of these sandstones ranges from 100 to probably 600 feet in thickness. The Shades and Pine sandstones are coarse, siliceous and conglomeratic at the base, grading into fine-grained, more thin-bedded sandstones above. Near the base of the Shades sandstone is the horizon of the Brock coal bed.

On the eastern edge of the Warrior coal field the Boyles sandstone member, believed to be equivalent to the Pine sandstone member, is the basal member of the Pottsville resting unconformably upon Mississippian rocks. The Boyles sandstone member is a white or gray siliceous sandstone, in places conglomeratic at the bottom. It is the "Millstone grit" of the Warrior coal field. Overlying the Boyles sandstone member are about 600 feet of sandy shale and thin-bedded to massive sandstone up to the base of the Black Creek coal group. Within this interval three coal beds are generally recognized. These are in ascending order, the Tidmore, Rosa, and Sapp, which respectively lie 20, 140, and 370 feet above the top of the Boyles sandstone.

The Black Creek Coal Group consists of the Black Creek, Jefferson, and Lick Creek beds, which occupy an average interval of about 75 feet.

About 80 to 260 feet above the Black Creek coal group is the Mary Lee coal group which consists of the Ream coal bed, the Lick Creek sandstone member, and the Jaggar, Blue Creek, Mary Lee, and New Castle coal beds, and occupies an interval of about 180.

About 300 feet of shale and thin beds of sandstone separate the Mary Lee group from the Pratt coal group above. This group consists in ascending order of the Gillespie, Curry, American, Nickel Plate, or Cardiff, and Pratt coal beds, within an average vertical distance of about 130 feet. Above the Pratt coal bed for about 275 feet are shale and sandstone up to the Cobb lower coal, which is separated by about 20 feet of shale and sandstone from the Cobb upper coal bed. The Gwin coal bed overlies the Cobb upper at about 130 feet. and about 180 feet above the bed is the base of the Brookwood coal group, consisting of the Carter or Johnson beds at the base and Milldale and Brookwood beds above, the group occupying an interval of about 90 feet. About 200 feet of sandstone and shale completes the section of Pottsville rocks exposed along the southeastern margin of the Warrior coal field.

Though some of the sandstones that occur in this formation are fairly persistent, most of them vary greatly in thickness and texture from point to point. The shale is commonly very sandy, and frequently upon fresh exposure presents the appearance of thin-bedded, argillaceous sandstone. Probable correlations of beds of this formation with those encountered in the deep wells in the Fayette district are discussed below.

UNEXPOSED ROCKS IN THE FAYETTE DISTRICT.

GENERAL STATEMENT.

The nature, character, and thickness of the rocks underlying the surface of the Fayette district are not well known. A few facts relative to them have been obtained by a study of some of the upper beds at places where they outcrop in this district and adjacent to it, but by far the larger part of the present knowledge of them has been obtained from the logs of deep wells, drilled in search of oil, gas, and coal. All of the logs of these wells that have been obtained have been platted to scale, and arranged on Plate II with reference to their geographic position and the height of the mouth of each well above sea level.

Difficulty in making correlations from well records.—A careful study of Plate II (in pocket) will make evident the fact that well logs of churn drills cannot be relied upon for detailed correlations, for the reason that in drilling only the well-marked changes in character of the beds can be detected with certainty even by trained observers. By this method only the general character and sequence of the beds may be used as a guide in correlation, the very valuable paleontological evidence furnished by the fossils of the beds being destroyed in drilling. Unfortunately, core drills have not yet penetrated the rocks of this district to a sufficient depth to furnish the paleontological data so greatly needed. The greatest single source of error in making correlations from churn drill logs lies in the fact that all drillers, from the nature of the business, do not have a uniform system of identifying and naming the rocks which they encounter. Each driller, therefore, names the pulverized material brought up by the bailer according to his own standards. Errors in making and in noting measurements to the strata encountered, and the failure at times to detect the presence of thin coal beds, especially if they are encountered in soft black shale, also tend to render less valuable the use of well logs in correlating rocks of widely separated districts.

PENNSYLVANIAN SERIES.

POTTSVILLE FORMATION.

With the exception of a comparatively thin covering of sand, clay, and gravel, of Cretaceous and younger age, the rocks penetrated by the drill in the Fayette district appear to belong entirely to the Pottsville formation. This conclusion is based largely upon a comparison of the coal beds and prominent beds of sandstone of the well sections with the generalized section of the Pottsville formation where it is exposed on the eastern edge of the Warrior field. For convenience of comparison attention is directed to Plate II.

Correlation of coals of the well sections.—In well section F ten coal beds have been reported which appear to fall into groups similar to the generalized section of the Pottsville formation. By assuming that there is a general decrease in thickness of the Pottsville westward from Birmingham Valley, which is generally thought to be probable, the most prominent group of coal beds in well Section F, composed of coal beds numbered 28, 30, 32, and 34, appears to correspond somewhat closely with the Mary Lee coal group of the generalized section. On this basis of comparison the lowest of this group, No. 34, may be equivalent to the Ream bed; the Jaggar bed may be either No. 32 or No. 30; and No. 28 either the Blue Creek coal bed or the Mary Lee bed. The fact that a fairly persistent sandstone separates the Blue Creek and Mary Lee beds in the generalized section, together with the distance between beds, suggests that No. 28 is more nearly equivalent to the Blue Creek bed. If this is true coal No. 19 in well section H, which overlies a sandstone, may be the Mary Lee bed, in which case the Newcastle coal, if present, has not been recorded in the well sections.

Below this coal group in well section F occur two coal beds, Nos. 38 and 42, which are comparable, respectively, to the Lick Creek and Black Creek coals of the Black Creek coal group. The distance between these two groups in well section F and the generalized section are practically the same. The interval from the Black Creek coal to the Sapp coal in the eastern part of the Warrior field averages about 230 feet, in comparison with 160 feet between what is assumed to be the Black Creek coal and the next one below (No. 49) in well section F, thus leaving the identification of the latter in considerable doubt.

In the generalized section the Pratt group of 5 coal beds occupies an interval of about 130 feet and lies 300 feet to 430 feet above the top of the Mary Lee coal group. In well section F two coal beds, Nos. 13 and 20, occupy an interval of 130 feet at a distance of 300 to 430 feet above the four coal beds of this section, which appear to be comparable in part at least to the Mary Lee group. These also appear to be the same as coal beds Nos. 12 and 17, respectively, of well section C, and possibly coal beds Nos. 7 and 11 of section A. Unfortunately, the upper 475 feet of section F is not available, nor the section of the Brennen core drill hole located a few feet distant from Providence well No. 5. The few scattered coal beds reported in the upper part of the wells are doubtfully correlated as follows:

If it is assumed that the tentative identification of the Mary Lee group of coal beds in the Providence well No. 5 (section F) is correct, coal No. 5 of this well section, and coal No. 14 of well section G (Providence well No. 1) seem to occupy a position about 550 feet above the Mary Lee group, or about 125 feet above the Pratt coal group of the generalized section. The thin coal No. 15 of the Providence well No. 5 (section H) may belong to the same horizon, but appears to be somewhat higher. These coal beds seem to be too low to belong to the Cobb coal group, and to be somewhat too high for the Pratt group, though the presence of the thick sandstone No. 7 below this coal in section F suggests that an increase in interval between the Pratt coal and the Nickel Plate coal may, in the Fayette district, bring the former up to this horizon. The Cobb coal group appears to be represented by coal beds Nos. 5, section A; 6, section C; 11, section D; 13, section H; and 12, section L.

The Gwin coal bed, which in the generalized section is shown about 140 feet above the Cobb upper coal, appears, from the above correlation, to be represented by coal No. 4 of section C, and the small lens of coal near the base of sandstone No. 8, section E. The Carter or Johnson coal appears to be present in section D as coal No. 5; in section I as coal No. 9, and in section L as coal No. 8. If this correlation of the Carter or Johnson coal bed is correct, the Milldale coal above it is not represented in the well sections, the Brookwood coal being shown only as No. 3 of section H. In section H sandstone No. 5 is equivalent to sandstones Nos. 2, 3, and 4 of section G; sandstone No. 3, of E; sandstone No. 2, and the upper part of No. 3 of section D; sandstone No. 1, of section C, and No. 2 of section B. It probably lies above the top of section A. In sections I and J the top of this sandstone is in contact with the basal conglomerate of the Cretaceous, and in the river bluff at Providence well No. 4 (section C). A correlation of the outcropping beds based upon the identification of this sandstone in areas where it is exposed is made in the chapter on the "Areal distribution and character of the outcropping rocks."

These tentative long-distance correlations are, of course, made suggestively only. They might have been made more conclusive if the positions of more coal beds in the well sections were known. At best they will very likely be subjected to considerable revision when a sufficient fund of paleontologic evidence has been accumulated, or the records of suitably distributed wells are available.

Correlation of the other strata of the well sections.—In this report no attempt will be made to correlate in detail the strata reported in the deep wells. However, in all attempts to trace a horizon from place to place by well records alone, it is best to remember that the tendency of drillers is to report greater thickness of sandstone than actually occur. Many hard, compact beds of sandy shale are mistaken for sandstone, because the appearance of the pulverized material from such beds generally shows a large percentage of sand grains, the beds offer relatively great resistance to drilling, and the wear on the bits is similar to that produced by sandstone. In well section K the relatively great thickness of sands Nos. 10 and 12, as compared with the other well logs, strongly suggests that those beds are made up principally of compact, sandy shale in which occur numerous thin beds of sandstone. Also in well section A, the beds Nos. 3, 14, 16, and 20, characterized by the driller as "Limes," "broken lime," etc., are most probably not limestone at all, but somewhat calcareous shale and sandstone. No. 3 of this section is very probably a calcareous sandstone. Also, Nos. 17, 22, and 23 of well section B, though probably containing a noticeable amount of lime carbonate, most likely would not be classed by the drillers themselves as limestone if the beds were exposed at the surface.

The sandstone found to contain gas in paying quantities in Providence well No. 1 is known as the Fayette gas sand. This sand is shown at the base of sections G, H, I, and K, and is sandstone 26 of section L. There is doubt as to the position of this sand in the well near Kennedy, as shown by section M. The elevation of this well was not obtained and the tentative correlation based upon stratigraphic sequence alone suggests sandstone No. 18 as being equivalent to the Fayette gas sand, but it is possible that sandstone No. 18 of section M is the same as either sandstone No. 22 or 24 of section L.

Numbers 40 to 43 inclusive of section F are very probably equivalent to the Fayette gas sand, as are also numbers 18 to 20 inclusive of section B, and No. 22 of section A. Sandstone No. 31 of section D appears to overlie the Fayette gas sand, but the nature of the log leaves this in serious doubt.

The very thick sandstones, Nos. 28 and 29 of well section L, appear to be equivalent to sandstones 25 to 31 inclusive of well section A, and the shale beds Nos. 26, 28, and 30 of well section A seem to be absent in well section L. The exact position in the Fayette district of the sandstone in the generalized section of the Pottsville formation on the eastern edge of the Warrior field is somewhat in doubt. If the Fayette gas sand is one of the sandstones of the Black Creek coal group, as correlated above, the very thick sandstones shown at the base of well sections A and L may be correlated with the shale, sandstone, and coal of the generalized section from a short distance below the Black Creek coal to and possibly including some of the Boyles sandstone member. A very massive sandstone is locally found below the Black Creek coal at places along its outcrop on the northern side of the Warrior coal field, and this sandstone may increase in thickness southwest across the coal field, becoming several hundred feet thick in the western part of the Fayette district, and possibly uniting at base with the Boyles sandstone member. The absence in well section L of the three beds of shale, Nos. 26, 28, and 30, of well section A, suggests thickening of the sandstones of this horizon from east to west.

As already stated, the Boyles sandstone member of the eastern side of the Warrior coal field is tentatively correlated with the Pine sandstone member of Birmingham and Cahaba valleys, east and northeast of Birmingham. The stratigraphic position of this sandstone is shown on the generalized sections of the rocks of these valleys, at the bottom of Plate II.

Probable Character of the Rocks Below the Wells of the Fayette District.

A very important factor which must not be overlooked in considering the nature of the beds to be found below the wells in the Fayette district is the unconformity* at the base of the

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*The Birmingham folio, No. 175 U. S. G. S. by Charles Butts.

Boyles sandstone on the eastern side of the Warrior coal field. This unconformity represents a long period of time during which the Mississippian rocks constituted a land surface and were being removed by streams. Along the northeastern edge of the Warrior coal field this hiatus includes all of the Pottsville formation below the Boyles sandstone member, say 500 feet; all of the Parkwood formation, say 2,000 feet; and all but about 60 feet of the Pennington shale, say 200 feet, in all 2,700 feet. The Boyles sandstone member thus rests directly upon the eroded surface of the Pennington shale. If similar conditions prevailed in the Fayette district, the drill would penetrate only a few feet of red, gray, green, and black shale below the Boyles sandstone member before entering the Bangor limestone, or its equivalent, the Floyd shale. This unconformity may be either greater or smaller in the Fayette district than on the eastern border of the basin. If the former is true all of the Pennington shale and even the Bangor limestone or the Floyd shale may have been removed from the old land surface before the sea again covered this region and the deposition of the Pottsville sandstones began.

If the unconformity decreases in magnitude from the northeastern edge of the Warrior coal field toward the Fayette district, all of the Pennington shale (shown in the generalized section at the bottom of Plate II) may be present, and under this formation the Bangor limestone or its equivalent part of the Floyd shale in its full thickness. If geologic conditions were similar in the Cahaba and Fayette districts during the deposition of the rocks below the Pine sandstone member, then the beds should be prevailingly shaly for about 500 feet below the Boyles sandstone member, and the next 500 to 700 feet of strata should be made up principally of the massive, siliceous, conglomerate Shades sandstone which forms the basal member of the Pottsville formation in Cahaba Valley east of Birmingham. It seems very doutbful if the Parkwood formation is present in the Fayette district, since it thins rapidly westward from the Cahaba Valley, and is absent along the eastern side of the Warrior coal field. If the Parkwood is present, it probably is very much thinner than it is in Cahaba Valley, and probably consists largely of sandy shale.

The Pennington shale and Bangor limestone are very probably present in the Fayette district, but there is no means of predicting whether or not these phases of sedimentation or that of their equivalent, the Floyd shale, occurred there. If all of these formations are present, they probably have a combined thickness of 1,000 to 1,200 feet. The Fort Payne chert and the underlying formations, as shown in the generalized sections of Plate II, are widespread and are most probably present in the Fayette district.

It seems probable that the section below the "Coal Measures" of the Fayette district is the same as that part of the generalized section for Birmingham Valley, beginning 100 feet above the base of the Pennington. The depth to the Hartselle sandstone or Chickamauga limestone or any other desired horizon very probably can be computed from the generalized section of the Warrior coal field and the section in Birmingham Valley by assuming that the bottom of the Boyle sandstone member lies 50 to 100 feet above the bottom of the Pennington.

EXPOSED ROCKS IN THE FAYETTE DISTRICT.

As stated above, the rocks exposed at the surface in the Fayette district are separable into two great systems, the Carboniferous below and the Cretaceous above.

At the close of the Carboniferous deposition this region was elevated above sea level forming a land area from which material was removed by the streams and deposited in the surrounding sea. This continued throughout the Triassic and Jurassic time, but near the beginning of the Cretaceous period the land sank and in the water which covered it sand, gravel, and clay from the adjacent land areas were deposited. Thus the surface of unconformity represents the time during which this was a land area and no material was being deposited upon it.

Because of folding in the Carboniferous beds previous to the deposition of the Cretaceous strata the bedding planes of the latter were not laid down parallel to those of the former, but lay across or unconformably upon the eroded edges. Because of this unconformability, the folds in the Cretaceous beds give no clew to the character and amount of or disturbance in the Carboniferous rocks lying below. In this district gas is found only in the Carboniferous rocks, and in order to determine accurately the positions of the anticlines and synclines in them not only good exposures of the rocks uniformly over the area to be mapped are required, but also some of the beds must have such characteristics as will afford a means of identifying them at all places where they are exposed.

Two colors are used on the map to distinguish these general subdivisions of the outcropping rocks,—blue for Carboniferous, green for Cretaceous and Tertiary, the uncolored portions representing alluvium and wash of Recent age. No attempt has been made to differentiate portions of the Cretaceous, Tertiary and Recent beds, since such a differentiation is of no value in an investigation of the oil and gas possibilities of the district.

AREAL DISTRIBUTION AND CHARACTER OF OUTCROPPING BEDS.

POTTSVILLE FORMATION.

Although Carboniferous rocks of Pottsville age are present within about 400 feet of the surface at all points in the area covered by the topographic map, the beds actually come to light in relatively small portions of it. These exposed areas are at such places where streams have cut through the Cretaceous and Tertiary blanket of sand, gravel, and clay, which once covered the entire surface, into the Carboniferous strata below. In places the streams have laid bare Pottsville beds over considerable stretches of valleys. At many of these places the older rocks have since been covered by thin deposits of alluvium and wash from adjoining hill slopes, thus effectively concealing them from view. On the map the portion colored blue represents areas in which Carboniferous beds have been seen, though a thin mantle of unconsolidated material, usually sand, covers the Pottsville strata over most of each area. A brief description of the exposures of Pottsville rocks noted in these areas is given below.

In reconnoissance work ahead of topographic mapping, where, as in the present case, all lines of traverse were run out and plotted in the field, the time available for field work did not permit the tracing of outcrops throughout their entire length. Because of the well known tendency of sandstone beds to change rapidly in thickness and character from point to point, there is a possibility of error in identification. For this reason it seems best to describe the exposures examined in such way that any errors of correlation that may have been made can be easily located by those who study the area in more detail.

Exposures of Pottsville rocks on Clear Creek.—Carboniferous strata are exposed along both sides of the valley of Clear Creek from its mouth as far north as the valley has been mapped, a distance of about 4 miles. The floor of the valley is alluvium which conceals the Carboniferous rocks, except at a few places along the banks of the stream.

On this creek, a short distance below the road crossing in Sec. 2, T. 16 S., R. 11 N., the following is exposed from the top of the bluff down to the creek:

CLEAR CREEK VERTICAL SECTION, SHOWING OUTCROPPING ROCKS.

	Concealed at top of bluff	Ft.	Inch.
(1)	Sandstone, very thin-bedded, greenish and shaly	6	
(2)	Shale, brownish, compact, sandy	8	
(3)	Sandstone, or sandy shale, very compact, greenish	12	
(4)	Concealed with shale and sandstone debris	18	
(5)	Sandstone or sandy shale, thin-bedded, greenish to brown	5	
(6)	Sandstone, massive, medium-grained, cliff-making, greenish to brownish	10	
(7)	Concealed	15	
(8)	Sandstone, reddish brown, 5-foot massive, cliff-making ledge in the middle	12	
(9)	Concealed (brown shale, and some thin-bedded sandstone debris)	21	
(10)	Shale, bluish to brown, blocky, sandy	10	
(11)	Coal		14
(12)	Underclay yellowish brown, sandy	4	
(13)	Shale, black to dark blue, coarse, to water	5	
(14)	Sandstone in bed of creek		
	Total	127	2

A short distance up the creek above the road crossing the lowest sandstone (No. 14) shows for 10 feet above water level. It is here very massive, somewhat coarse, reddish to gray in color, and is overlain by about 20 feet of sandy shale which weathers brown at the base, but is somewhat more bluish at the top. A small coal bed (No. 1) occurs in this shale about 15 feet above the top of the sandstone. About

42 feet above this coal on the hillside a thin, cliff-making sandstone is well exposed. This sandstone may be traced in continuous outcrop to where it crosses the public road ⅛ mile west of the creek. At that point no coal was seen, but a thin bed of soft, white, red and dark clay, about 24 feet below the sandstone may mark the horizon of the coal bed. At this exposure the upper cliff-making sandstone is represented by a badly weathered sandy shale or shaly sandstone, the massive layers having disappeared. The outcrop of the sandstone below the coal bed (No. 14) was traced northward along the west side of Clear Creek for half a mile in continuous outcrop, where it was found to consist of 16 feet or more of massive, coarse, gray, cliff-making sandstone at the top and about 10 feet of thinner-bedded, somewhat shaly sandstone below. This sandstone is here underlain by about 8 feet of dark brown, sandy shale to the level of the creek which appears to be flowing over a thin sandstone.

The above section on Clear Creek is a fairly typical one for the exposed Pottsville beds in the area mapped, and, since it covers that portion of the geologic section most frequently exposed, it may be used as a basis for local correlation. Northward from this exposure the sandstone of the Clear Creek section becomes more massive, and is exposed at many places along Clear Creek in almost vertical cliffs from 10 to 50 feet high.

At the road crossing on Clear Creek at Cottons Mill, Sec. 35, T. 15 S., R. 11 W., the top of what appears to be sandstone No. 14 of the Clear Creek section outcrops about 45 feet above water level. This bed is here about 30 feet thick with a massive cliff-making ledge 3 feet thick at the top and another 10 feet in thickness near the bottom. About 20 feet of brown shale in which are imbedded thin sandstones underlie this sandstone down to creek level. The rocks are unexposed for 40 feet above this sandstone along the road west from the bridge, and the coal bed of the Clear Creek section is not visible. The first rocks exposed above are 5 feet of whitish to blue clay shale outcropping in a spring by the roadside. Overlying this shale for 15 feet are poor exposures of thin-bedded sandstone. A thousand feet farther west on this road and about 50 feet higher up the hill is 10 feet of coarse, massive, reddish to whitish sandstone, very deeply weathered, overlain by Cretaceous sand. This appears to be sandstone No. 6 of the Clear Creek Section.

On the road one-third of a mile southeast of Cottons Mill, the lower portion of sandstone No. 14 of the Clear Creek Section is exposed in the road in front of a house. About 100 feet farther east a coal bed, possibly that of this Section, is also exposed on a level with the standstone. The coal is only a few inches thick, with a yellowish to whitish under clay about 4 feet in thickness. Below the clay is 20 feet of light brown, somewhat fissile shale on the top of a massive sandstone in the bottom of the adjacent ravine. The abrupt change at this place from sandstone to clay, coal, and shale strongly indicates a fault. If the sandstone is No. 14, and the coal the same as that of the Clear Creek section, the downthrow of the fault is to the east, the displacement being between 40 and 60 feet. For want of time the writer was unable to trace the outcrop of this sandstone along both sides of the valley and thus definitely correlate it with the beds described in the Clear Creek section.

At the bridge over Clear Creek, one mile east of Bankston, the massive sandstone below the coal in the Clear Creek section is probably just below drainage. This coal horizon apparently is marked by shale debris which covers the surface for about 30 feet above the creek. The first stratum exposed along the road west from the bridge is a dark brown, sandy shale which outcrops from 30 to 85 feet above the creek. Within this shale are a few thin layers of greenish, shaly sandstone and a 10-foot bed of thin-bedded, compact, greenish sandstone or very sandy shale which is 60 to 70 feet above the creek. This appears to occupy the same position as sandstone No. 8 of the Clear Creek section. From 85 to 100 feet above the creek is a greenish to brown blocky shale showing concretionary weathering, which is overlain by 8 feet of cliff-making sandstone, the lower 6 feet of which is very massive. This is sandstone No. 6 of the Clear Creek section. Above this sandstone the rocks are concealed except occasional small outcrops of sandy shale and thin-bedded greenish sandstone. On this road, northeast from Clear Creek, the strata described above outcrop and, though deeply weathered, are easily correlated. Here sandstones Nos. 5 and 6 of the Clear Creek section appear to be at least 25 feet thick with massive beds towards the top. They are so badly altered by weathering that the contact between the carboniferous beds and the overlying Cretaceous sand cannot be determined with certainty. Northward along the ridge road some of the beds come to the surface in a few poorly exposed outcrops, which offer little opportunity for making accurate correlations. In N. W. ¼ of Sec. 1, T. 16 S., R. 11 W., a coal was encountered in a well dug for water, which appears to be the same as the one in the Clear Creek section. About 50 feet above it a massive cliff-making sandstone layer 5 feet in thickness outcrops along the hillside. Below this sandstone are a few small exposures of brown, sandy shale, containing occasional thin layers of greenish to reddish sandstone. Overlying this sandstone to the top of the hill is deeply weathered debris of sandstone and reddish sandy shale mixed with Cretaceous sand. Half a mile north of this locality a 4-inch coal bed is reported to be in a gully about 100 yards east of the road forks. A thin bed of white clay was found at this place but the coal, if present, was concealed. This bed is 40 feet higher than the one in the well. The character of the surrounding exposures is such as to make it doubtful if these two outcrops are of the same coal. The latter may prove to be a higher coal than the former and to occur at the horizon of the white clay mentioned as being exposed in the road near the Clear Creek section.

On the west side of Clear Creek, about half a mile north of the railroad, the cliff-making sandstone No .4 of the type section forms a well-marked cliff along the edge of the flat-topped hill. Below this is 10 feet of dark brown, sandy shale, which shows concentric weathering, and then a distance of 18 feet in which the rocks are concealed. Below the concealed part is 10 feet of greenish, thin-bedded, compact, cliff-making sandstone or very sandy shale, which shows well-marked joint planes similar to No. 8 in the Clear Creek section. Underlying this sandstone is 18 feet of yellowish brown shale poorly exposed which in turn overlies about 5 feet of thin-bedded, greenish, cliff-making sandstone. The remainder of the section down to creek level is concealed by debris and alluvium. The horizon of the coal of the Clear Creek section is a short distance below the lowest sandstone exposed at this point. At the railroad cut through the southern end of the hill the lowest cliff-making sandstone, which is probably below No. 8 of the

Clear Creek section, appears to be partially exposed about 50 feet above the track, and 20 feet of dark brown, somewhat fissile, sandy shale is exposed in the cut. The upper half of this shale contains a few thin layers of shaly sandstone. This shale is probably equivalent to No. 10 of the Clear Creek section. It is much thicker and the horizon of the coal bed of the Clear Creek section is above the cut.

At the first cut on the railroad east of Clear Creek about 10 feet of yellowish brown shale with thin sandstone layers is exposed at the base of the cut, which may be equivalent to the upper part of the shale, described above, in the railroad cut on the west side of Clear Creek valley. This shale is overlain by 10 feet of darker brown sandy shale free from sandstone beds and weathering in concentric concretion-like layers. About 40 feet above the track 5 feet of rather massive sandstone with thin-bedded sandstone below appears to be the equivalent of No. 8 of the Clear Creek section.

From this railroad cut David White secured a small collection of fossil plants which, though not sufficient for close cerrelation of these beds, suggest to him that the beds are later than the Pratt coal group, and possibly as young as Brookwood.

About ¼ mile south of this exposure, at the iron bridge where Clear Creek empties into North River, the sandy dark brown and bluish shale with thin layers of sandstone extends for about 40 feet above water. Overlying it is 7 feet of rather massive, cliff-making sandstone, with 8 feet of sandy brown shale above, to a second 8-foot massive layer of cliff-making sandstone, probably No. 8 of the Clear Creek section.

Exposures of Pottsville rocks on Deadwater Creek.—In the N. E. part of the N. E. ¼ of the S. E. ¼ of Sec. 33, T. 15 S., R. 11 W., a coal bed 10 or 12 inches thick is exposed at the base of the hill near the mouth of a tributary to Deadwater Creek from the north. The following section obtained at this point is used in correlating the exposed strata of the vicinity with those described in Clear Creek Valley.

THE DEADWATER VERTICAL SECTION SHOWING OUTCROPPING ROCKS ON DEADWATER CREEK.

		Thickness Feet
	Cretaceous sand at top of hill	
(1)	Sandstone, thin-bedded, shaly, greenish, or very sandy shale, containing a few thin, more resistant beds of sandstone	42
(2)	Sandstone, massive, gray to brownish, cliff-making, weathers to coarse, light yellow sand	9
(3)	Concealed by sandstone debris from massive bed above	11
(4)	Sandstone, massive, gray, cliff-making	4
(5)	Concealed by boulders of sandstone from above	10
(6)	Sandstone in massive, cliff-making layers	3
(7)	Concealed by sandstone boulders from above	10
(8)	Sandstone, massive, cliff-making bed in two or three layers	5
(9)	Concealed by sandstone boulders from above	27
(10)	Shale, blocky, sandy, bluish brown at top to very dark brown at bottom	6
(11)	Coal, about	1
(12)	Clay, yellowish, sandy, fossiliferous	2
(13)	Dark brown blocky shale	2
(14)	Concealed below level of tributary valley	7
	Total	139

Sandstone No. 8 of the Deadwater section seems to be at least a part of No. 8 of the Clear Creek section, but the latter may include also everything between Nos. 4 and 8 of the Deadwater section, since all of these sandstones appear to thicken from north to south across the area mapped. Sandstone No. 2 of the Deadwater section is probably equivalent to sandstone No. 6 of the Clear Creek section, though this bed may also thicken to include Nos. 3 and 4 of the former. Numbers 1 to 5 inclusive of the Clear Creek section appear to be equivalent to all or a portion of No. 7 of the Deadwater section. From the data at hand the coal noted in the Deadwater section appears to be the same as that given in the Clear Creek section. The associated beds of shale and clay are very similar and the positions of the cliff-making sandstone layers above, together with the general appearance and character of each, add strength to this correlation.

A tributary of Deadwater enters the valley at the point where the Deadwater section was measured. On this stream two other coal outcrops were noted, one in the N. W. ¼ of Sec. 34, on a small tributary about ¾ mile northeast of the outcrop noted in the Deadwater section, and another west of the stream at a spring in the central part of the N. W. ¼ of the S. E. ¼ of Sec. 28, T. 15 S., R. 11 W. These three outcrops appear to belong to as many different coal beds. The second one mentioned seems to overlie sandstone No. 8 of the Deadwater section; the one exposed in the spring is probably about 15 or 20 feet above sandstone No. 2 of that section.

The coal in Sec. 34 is exposed at one place in the valley where it has been mined in a small way by stripping the thin covering of Cretaceous wash. It is said to have a total thickness of 18 inches of solid coal of good quality overlain by 4 inches of shale, above which is two inches of coal. This bed appears to rest upon a coarse massive gray to greenish sandstone (probably No. 8 of the Deadwater section), 10 feet of which is exposed in the stream below the outcrop of coal. This sandstone appears to dip down stream at a rate almost equal to the fall of the stream and it seems to be the massive 20-foot sandstone exposed at the stream forks ¼ mile west. On the hillside about 50 feet above this coal outcrop a ledge of massive gray sandstone 6 feet thick protrudes from the Cretaceous sand. This appears to be sandstone No. 2 of the Deadwater section.

From the exposure at the forks of the stream ½ mile north of the place where the Deadwater section was measured, the massive, cliff-making sandstone has been traced in almost continuous outcrop northward to the coal exposure at the spring in the central part of the N. W. ¼ of S. E. ¼ of Sec. 28, T. 15 S., R. 11 W. This coal outcrop is now concealed in a bog below the spring, but it has been stripped by the owner of the land for local use. The bed is about 8 inches thick and is overlain by about 6 feet of soft bluish clay shale.

From a study of the exposed rocks between the coal outcrop in the spring and the Fayette gas field, it seems that sandstone No. 2 of the Deadwater section is probably equivalent to the massive sandstone exposed in the cut at Gas Wells station, and also the same as No. 5 of well section H. Pl. II, in which case the coal in the spring is equivalent to coal No. 3 of well section H, which has been tentatively correlated in the study of these well sections with the Brookwood coal. If this is a correct correlation, the coal described above as exposed on the small tributary in the N. W. ¼ of Sec. 34 is probably the Milldale bed, the coal of the Deadwater section being the Carter or Johnson bed. This correlation, it should be observed, does not agree with the conclusions reached by McCalley who* considers the coal exposure along the Deadwater and Clear creeks to be the Cobb coal group.

It is to be regretted that sufficient paleontological material is not available to make possible a positive identification of these coal beds. An examination by David White of a few small collections of fossil plants obtained from a horizon a short distance below the coal bed of the Deadwater section, which he considers to be younger than the Pratt coal group, and probably not later than the Brookwood coal, still leaves unsettled the question of whether these coals belong to the Cobb group or to the Brookwood group. The writer's correlations of these coal beds is by no means satisfactory to himself, but are presented as a suggestion that they may prove to belong to the Brookwood group rather than the Cobb group.

It is possible that a fault occurs between the coal outcrop of vertical section B and the coal exposure to the northeast in Sec. 34, but no direct evidence of such fault was seen in the field, possibly because the rocks in the place in which it seems most likely to occur are concealed by wash from the adjacent hills. If this fault is present, it crosses the stream less than ½ mile north of the location of the Deadwater section, with a north-northwest-south-southeast trend, and the downthrow is probably to the southwest with a displacement of about 75 feet. Attention is called to the possible existence of this fault in order that too much reliance may not be put in the structure contour lines in this locality until it has been examined more thoroughly than was possible in the time allotted to this work.

At the mouth of a small tributary of Deadwater Creek from the west, the cliff made by the massive portion of sandstone No. 8 of the Deadwater section is only a few feet above valley level. About 100 yards southwest of this outcrop, sandstone No. 2 of the section is exposed at the top of a bluff on the south side of this tributary. Here the interval between these beds is composed very largely of sandstone, most of which is thin-bedded, but here, as at most other exposures of these beds, the cliff-making portions are represented by harder, more massive layers. Sandstone No. 2 is exposed for ½ mile west along this tributary to where it passes below stream level. Sandstones Nos. 4 and 6 are also present here in typical outcrop.

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*McCalley, Geol. Survey of Alabama. Report on the Warrior Coal Basin. 1900, pp. 169 and map.

At the forks of Deadwater Creek in the central part of Sec. 33, sandstone No. 8 of the Deadwater section outcrops on both sides of the valley near the base of the bluffs. It also outcrops northward along the east fork, for more than ½ mile before going under cover. Sandstone No. 4 of this section caps the tops of the bluffs on one or both sides of the stream as a somewhat massive cliff-making, grayish sandstone, for about 1½ miles. At some places along this outcrop the cliff-making qualities of the bed disappear and its outcrop is concealed by Cretaceous wash from above. This bed can be traced, however, with certainty to where it goes under drainage in contact with the Cretaceous.

Sandstone No. 4 of the Deadwater section is also exposed along the west fork of Deadwater Creek for about ¾ mile. It goes under cover at a point where sandstone No. 2 of the same section is exposed in the bluff above it. Number 2 is here a gray, cliff-making sandstone, which may be traced in uninterrupted exposure for a half a mile upstream where it passes below valley level in contact with the Cretaceous sand.

South of the location of the Deadwater section no good exposures were observed on the east side of Deadwater Creek valley for about ½ mile. In the S. W. ¼, Sec. 34, a small tributary enters Deadwater Creek from the east, and along the steep bluffs of this stream the rocks from sandstones Nos. 2 to 8 inclusive of the Deadwater section are exposed in continuous outcrops for ¾ mile. Here, practically the whole interval is made up of sandstone, but the massive cliff-making zones are sufficiently prominent to admit of a close correlation. Midway between this stream and where the Bankston-Fayette road crosses the valley exposures of sandstone Nos. 6 and 8 of this section were noted at the mouth of another small tributary from the east. North of this road, about halfway between Deadwater Creek and the cross roads on the hill to the east, sandstone No. 2 is exposed near the top of a small secondary ridge. This outcrop is traceable to another exposure of sandstone No. 2 on the road just west of the above cross roads. On the west side of Deadwater Valley cliffs of sandstone are frequent. Tributaries to this creek from the west have cut deep narrow gorges near their mouths through sandstones Nos. 2 to 8 inclusive of the Deadwater section, the more massive of the sandstones appearing as cliffs. These exposures do not extend up the smaller streams more than a few hundred yards before they pass under the Cretaceous cover.

An exposure of sandstones Nos. 2 and 4 occurs on the Fayette-Bankston road about half way up the western side of the valley. At this place the following section was noted:

ROCKS EXPOSED ON FAYETTE-BANKSTON ROAD ON WEST SIDE OF DEADWATER VALLEY, CORRELATED WITH THE DEADWATER SECTION.

Cretaceous sand to top of hill.	Feet.
Sandstone, dark gray, cliff-making (No. 2)	6
Sandstone, thin-bedded, thick-bedded at the base (part of No. 3)	8
Concealed	10
Sandstone, thin-bedded, shaly	5
Massive, gray to greenish, cliff-making sandstone ledge (No. 4)	6
Shale, light yellow, clayey	5
Concealed (horizon of sandstone No. 8)	18
Shale, brown, massive, blocky, sandy	5
Concealed	8
Shale, brown, clayey, soft, changed to dark brown at bottom	18
Concealed to creek shale and sand debris	25
Total	114

At this place the position of the coal of the Deadwater section is probably at, or just below, the creek.

On Deadwater Creek, south of the Fayette-Bankston road, no good exposures occur for half a mile. Within this distance the rocks change from a downstream to an upstream dip. sandstone Nos. 8 and 4 of the Deadwater section again appear on the hillsides in low cliffs of compact thin-bedded greenish sandstone containing one or more massive layers. At a few places along the creek occur small exposures of the dark brown to bluish shale and thin-interbedded sandstones which occupy the position of No. 9 of the Deadwater section. At one locality the entire interval between sandstones 4 and 8 is occupied by light brown, very sandy shale containing a few thin layers of sandstone. All of the sandstones of the

Deadwater section decrease in thickness southward along this valley and no good exposures are present on the west side south of Bankston. On the east side of the valley what appears to be sandstone No. 4 is well exposed in the road about ¼ mile northeast of the station at Bankston. On the hillside east of the road at this point a massive ledge of sandstone (probably No. 2) protrudes through the Cretaceous sand. The following section shows the rapid change in the sandstones of both the Clear Creek and the Deadwater sections southward from the type localities:

SECTION ON "BYLER ROAD" EAST FROM BANKSTON.

		Feet
(1)	Reddish, sandy debris, probably concealing beds of badly weathered sandstone and reddish sandy shale for 25 feet below top of hill.	
(2)	Sandstone and shale, thin-bedded, badly weathered, reddish and greenish	13
(3)	Sandstone, thin-bedded, brownish with 1 or 2 somewhat massive layers (lower part probably horizon of sandstone No. 2 of the Deadwater section and sandstone No. 6 of the Clear Creek section)	14
(4)	Shale, grayish to greenish, very sandy	8
	Concealed (reddish, shaly, and thin-bedded sandstone debris)	35
(5)	Sandstone, greenish, thin-bedded, pronounced joint planes (probably No. 8)	5
(6)	Shale, brown, blocky, somewhat massive with thin beds of sandstone	20
	Total	95

Along the hillside south of this exposure the somewhat prominent sandstone (No. 3 of this section) is exposed as a low cliff at a number of places where one or two layers of it become massive. It here resembles very closely sandstone No. 2 of the Deadwater section. The beds rise southward to the point of the hill at the railway cut and either sandstone No. 2 or No. 8 is exposed at almost all points throughout this distance.

A small tributary enters Deadwater Creek at its junction with Baker Creek, about one-third mile north of Bankston. Along this small stream the rocks show a relatively rapid dip upstream. Just below the forks in the stream, about ½ mile from its mouth, sandstone No. 8 of the Deadwater section is exposed on the hillside about 40 feet above; whereas at the forks this sandstone is only about 12 feet above the stream. Between this point and the mouth of the stream the horizon of the coal of the Deadwater section comes to the surface, but no coal could be found. About 20 feet below sandstone No. 8, at the fork of the small stream, a peculiar irregularly-bedded, somewhat massive, greenish, shaly sandstone is exposed in two layers, each about 3 feet thick and separated by about 4 feet of dark brown blocky shale. This sandstone seems to be just above the coal of the Deadwater section. It is very irregular in occurrence but thickens and becomes more sandy toward the southwest.

Farther up the stream sandstone No. 2 of the above section is present in a typical, cliff-making exposure, and below it sandstone No. 6 is represented by a thin bed of compact, cliff-making, greenish sandstone, 6 feet in thickness. Near the head of the south fork of this stream a massive yellowish, badly weathered sandstone protrudes from the Cretaceous sand a few feet above the stream. There is no way of determining the stratigraphic position of this bed which will be referred to as sandstone 1b. The rocks are concealed between this exposure and the nearest one of sandstone No. 2, about 1,100 feet downstream, and the dip between these two exposures is therefore uncertain. If the dip is uniform the horizon of this sandstone is between 75 and 100 feet above sandstone No. 2, and hence between 140 and 180 feet above the coal of the Deadwater section. At the exposure of this sandstone the dip appears to be somewhat less than at the last exposure of sandstone No. 2 on this stream, and the interval between these sandstones is estimated to be approximately 65 feet.

The first recognizable exposures up Baker Creek occur about 1 mile from its mouth. Here a massive cliff-making sandstone, believed to be No. 8 of the Deadwater section outcrops on both sides of the valley and may be traced along the east fork of this creek almost to the Woods deep well No. 1 (B) where it goes below drainage under Cretaceous cover, with a relatively rapid dip upstream.

Along the west fork of this creek sandstone No. 8 dips rapidly westward, passing below the valley within 1,500 feet, at a point where sandstone No. 4 of the Deadwater section appears below the Cretaceous cap on the hillside south of this stream. This sandstone is at creek level less than 1,000 feet farther north, and about 800 feet still farther upstream sandstone No. 1 b, described as above as being about 65 feet above sandstone No. 2, is exposed on the north side of the valley, about 60 feet above the stream. This sandstone is about 10 feet thick, very massive, yellowish, and deeply weathered. It very probably was a resistant bed near the tops of the ancient pre-Cretaceous hills, and doubtless materially affected the tograhy of that old land surface. The other exposures of shale and sandstones serve to make more positive the correlation of the sandstones.

On the north side of Little Pinney Creek, in the southeastern part of the N. E. ¼ of S. E. ¼, Sec. 16, T. 16 S., R. 11 W., the following is exposed:

SECTION EXPOSED ON LITTLE PINNEY CREEK.

		Feet
(1)	Cretaceous sand	
(2)	Sandstone, massive, cliff-making, grayish to greenish	3
(3)	Sandstone, thin-bedded, shaly, greenish	8
(4)	Sandstone, massive, cliff-making, grayish	3
(5)	Sandstone, thin-bedded, very shaly	4
(6)	Sandstone, massive, cliff-making, grayish	3
(7)	Shale, yellowish brown, sandy, blocky, 7 feet exposed at top with 6 feet at bottom concealed by shale debris	13
(8)	Sandstone, massive, gray, cliff-making	4
(9)	Concealed by sandstone and shale debris	19
(9b)	Sandstone, very irregular, bedded, shaly, brown to greenish sandstone below	4
(10)	Shale, dark bluish to brown, sandy, concretionary (to creek level)	10
	Total	71

The numbers given in the above section correspond to those of the Deadwater section with the addition of sandstone 9b, which comes into the section west and south of Bankston. Though the members 2 to 6 inclusive form a single sandstone 21 feet in thickness, the cliff-making strata within it appear to correspond closely to those of the Clear Creek and Deadwater sections, but if these do not belong to exactly the same horizons, the three sections are certainly of the same sandstone. The bluish brown shale (No. 10) at the base of the above section is the same shale as that of above mentioned sections, and the horizon of the coal of those sections is only a few feet, at most, below creek level. Sandstone No. 2 of this section appears to be only about 72 feet above the coal horizon here as against 83 feet in the Deadwater section, though the distance between the other beds and this coal appears to be practically the same, the entire variation being between sandstones Nos. 2 and 4. The cliff-making sandstone of the Deadwater section is traceable as ledges along the sides of the valleys of Little Pinney Creek and its tributaries below the outcrop described above, and spirit level lines were run to them at a number of places. The most westerly exposure of one of these beds is on a small tributary of Little Pinney Creek in the S. E. ¼, S. W. ¼ of the S. E. ¼ Sec. 16. Here a massive, brownish green sandstone a few inches thick protrudes from the Cretaceous cover, at a small waterfall in the stream. Its identification is very uncertain, but it most probably is the ledge called sandstone No. 4 in the Deadwater section.

On the north fork of Little Pinney Creek in the N. W. ¼ of the S. W. ¼ Sec. 15, T. 16 S., R. 11 W., a massive sandstone which appears to be No. 8 of the Deadwater section outcrops in the point of a hill just west of a house and north of the public road. This bed dips northeast and is exposed at two or more places on the stream for a short distance. Farther up this stream sandstone No. 2 is exposed and at the road crossing still higher up a massive, deeply weathered yellowish sandstone is exposed in contact with the Cretaceous sand a few feet above stream level. The identification of this bed is uncertain but it evidently is one of the upper sandstones exposed in this vicinity.

In the central part of Sec. 15, T. 16 S., R. 11 W., sandstone No. 8 of the Deadwater section is exposed as a narrow cliff on both sides of the valley of Little Pinney Creek at 40 to 60 feet above the stream. At places sandstone No. 9 b is also exposed as a greenish shaly, fossiliferous sandstone. This sandstone is exposed on the "Byler Road" in the extreme northeast corner of Sec. 22, and above it sandstone No. 8 is in typical outcrop. About 1,500 feet farther south on this road, a massive, deeply decayed sandstone is exposed, a portion of which is probably No. 2. The outcrops of these sandstones were traced along the south fork of Little Pinney Creek almost across the northern part of Sec. 22. The cliff-making beds along this creek are sandstones Nos. 4 and 6 of the

Deadwater section, both of which are at places quite massive. In the northern part of the S. E. ¼ of the N. W. ¼ of Sec. 22, a coal bed is said to occur in the bottom of the creek. The writer did not see its outcrop, but since the horizon of the coal of the Deadwater section is at about this level, it is possible that a coal is present there. If so, it is the only place where this coal bed is known to occur south of Bankston in the area mapped.

Portions of sandstones Nos. 2 to 6 of the Deadwater section are exposed along the "Byler Road" from Little Pinney Creek southward to Rock Creek above Dardon's Mill. About ¼ mile west of this mill a fine exposure of the sandstones of the Deadwater section occurs on the abandoned road just above where the "Byler Road" crosses Rock Creek, at which place the following section was noted:

SECTION ON ABANDONED ROAD ON WEST SIDE OF THE "BYLER ROAD," ONE-FOURTH MILE WEST OF DARDON'S MILL.

		Feet
(1)	Shale, reddish, sandy, deeply weathered, at top of hill	5
(2)	Sandstone, coarse, reddish, deeply weathered	5
(3)	Shale, sandy, whitish, deeply weathered, with pronounced vertical joints producing long rectangular blocks, with streaks of whitish clay	6
(4)	Sandstone and shale, massive, greenish beds at top, 3 feet thick, very deeply weathered, with 2 feet of light colored shale, then 2 feet of thin-bedded, greenish sandstone, then 4 feet of massive cliff-making greenish sandstone at base	11
(5)	Sandstone, greenish, thin-bedded, shaly	5
(6)	Sandstone, very massive, cliff-making, irregular bedded	5
(7)	Clay, shale, and sandstone, 3 feet of bluish, very sandy, very fossiliferous, clay and shale, with 1 foot of thin-bedded, greenish shaly sandstone below	4
(8)	Sandstone, thin-bedded, compact, cliff-making, ripple-marked, greenish	6
(9)	Shale, coarse, very sandy; bluish, brown, blocky to creek level	3
	Total	50

The numbers in the above section conform to those of the Deadwater section. The 3 feet of bluish fossiliferous clay of No. 7 appear to be the horizon of the coal mentioned above as being exposed in the S. W. ¼, Sec. 34, T. 15 S., R. 11 W., northeast of the locality of the Deadwater section. Many carbonized fragments of plants were seen in it.

One or more of the cliff-making beds of the Deadwater section are exposed along Rock Creek in Sec. 27, T. 16 S., R. 11 W. Sandstone No. 8, usually thin bedded, outcrops near creek level. Sandstones Nos. 4 and 6 are very massive in the central part of Sec. 27, and from this place to the point where they disappear abruptly below drainage in the S. E. ¼, N. W. ¼ of the section. It is believed that a fault crosses the creek at this point in nearly a north-south direction with the downthrow on the east side. A few yards above the place where the sandstones disappear in the creek bed with a sharp dip to the northwest, a thick, bluish brown, blocky shale, very similar to No. 9 of the section described above is exposed in the creek bank. Up the creek from this point only occasional thin beds of sandstone occur in the shales, the beds appearing to dip slightly to the southwest.

Exposures of Pottsville rocks on North River and small tributaries.—The area discussed under this heading lies in Secs. 23 and 26 in the extreme southeastern portion of the area mapped. At Dardon's Mill on North River, the exposed beds appear to consist of sandstones Nos. 4 to 8 inclusive, of the Deadwater section. Some of these cliff-making beds are seen along the river bluff for half a mile downstream, but because of scanty exposures none of them could be positively identified. About ¼ mile upstream the river washes the base of a high bluff on the north side in which the above named sandstones are exposed in a typical outcrop. Here beds Nos. 4, 6, and 8 are cliff-making. Bed No. 2 appears to have been eroded at this point, but on the hillside about ¼ mile northwest of this locality, it is exposed in continuous outcrop for half a mile.

A tributary enters North River a short distance above the bluff, along which occur numerous exposures of beds Nos. 4 and 6 and about ¾ of a mile from its mouth bed No. 2 goes below water level in contact with Cretaceous sand.

Exposures of Pottsville rocks on Davis Creek.—West of the outcrops in Secs. 16, 22, and 27, T. 16 S., R. 11 W., described above, no exposures of Carboniferous strata occur within the area mapped except at a few localities along Davis Creek below Fortenberry's Mill. At this place the following section is exposed:

SECTION ON DAVIS CREEK NEAR FORTENBERRY'S MILL.

		Feet
(1)	Cretaceous sand and conglomerate	
(2)	Reddish shale and thin-bedded sandstone, so deeply weathered as to be hardly distinguishable from the overlying unconsolidated sand	5
(3)	Sandstone, massive, reddish to light, very deeply weathered	5
(4)	Sandstone, massive, cliff-making, greenish	4
(5)	Sandstone, thin-bedded, greenish, shaly	5
(6)	Clay, bluish, sandy, containing carbonized fossil plants	3
(7)	Sandstone, somewhat massive, smooth-bedded, to water in creek below dam	6
	Total	28

In this section sandstones Nos. 4 and 7 may be equivalent to Nos. 6 and 8, respectively, of the Deadwater section. The 3 feet of clay appears to be the same as that described above as No. 7 of the section on Rock Creek. This correlation is supported by the statement of Mr. Fortenberry that a small coal had once been found a short distance above his mill at a point which appears to be at about this horizon.

By the roadside about ¼ mile south of Fortenberry's Mill a small exposure of massive, greenish sandstone, projecting from the Cretaceous sand, is tentatively considered to be bed No. 6 of the Deadwater section. No other exposure of Carboniferous beds was found on Davis Creek, except in the vicinity of White's Mill. Under this mill about 14 feet of massive greenish sandstone extends from the water below the dam up to road level. Above this is exposed about 4 feet of thin-bedded, greenish sandstone overlain by about 2 feet of somewhat massive sandstone up to the Cretaceous. About 200 yards east of the mill a small exposure of massive sandstone seems to be the upper part of the sandstone under the mill. There are no data at hand upon which to base a safe correlation of the sandstone exposure at White's Mill with those at Fortenberry's Mill. The former seems likely to be at least a portion of the sandstone of the Deadwater section. If this correlation is correct, the top of the massive bed under White's Mill is probably at or near the horizon of the cliff-making bed shown in the Deadwater section as No. 4. In the absence of positive data on this point, the above correlation is used in attempting to show the structure of the rocks along Davis Creek.

Exposures of Pottsville rocks on Box's Creek and tributaries. —Pottsville rocks are exposed along Box's Creek and its tributaries in Sects. 30 and 31, T. 15 S., R. 11 W.; in Sects. 35 and 36, T. 15 S., R. 12 W., and in Sects. 1, 2, 3, 9, 10, 11, 12, T. 16 S., R. 12 W. These outcrops consist of sandstone, sandy shale, and a single exposure of coal. The coal is exposed in a shallow pit in the valley near the N. E. corner of S. W. ¼ of the S. W. ¼ Sec. 1, T. 16 S., R. 12 W. No measurement of the coal could be secured, but it appears to be less than 18 inches thick. It is overlain by about 5 feet of reddish brown shale above which is 8 or 10 feet of sandstone near the top of which occur massive cliff-making layers. This sandstone appears to be No. 6 of the Deadwater section, what appears to be sandstone No. 4 of this section being exposed in typical outcrop above. The coal seems to be the same as that exposed on the western edge of the N. E. ¼, N. W. ¼, Sec. 34, T. 15 S., R. 11 W., and is probably 41 feet above the coal of the Deadwater section.

Southeast from this coal outcrop sandstones Nos. 4 and 6 of the Deadwater section are exposed in continuous outcrop to the forks of the stream, but beyond that point they lose their cliff-making character and exposures of them are poor. They seem to grade into sandy shale with thin layers of smooth-bedded sandstone. On the east fork of this little stream, in the southern part of Sec. 1 and the northern part of Sec. 2, a few outcrops of thin sandstone and a number of exposures of shale occur. On the west fork, sandstone No. 6 goes below drainage a short distance above the forks and exposures of sandy brown shale only and a few thin sandstones were seen on the stream above that point.

From a place northwest of the exposures of the coal bed, sandstones Nos. 4 and 6 of the Deadwater section are finely exhibited on the north side of the valley to its mouth. In a small stream a short distance north of this point sandstone No. 8, which underlies the coal bed, is well exposed as a very massive irregularly bedded greenish sandstone. This bed forms the low bluff along the western border of Sec. 2, and from this place northward to the railroad bridge over Box's Creek, where it is exposed on the south side a few feet above the railroad. At this place a large tributary enters Box's Creek from the north, up which scattered exposures of Pottsville beds occur for about 1½ miles. Sandstones Nos. 4 and 6 form low cliffs on the east side of this valley for about one mile, and sandstone No. 8 passes below drainage near the crossing of the Bankston-Fayette road. Near the eastern edge of the S. W. ¼, S. E. ¼, Sec. 35, T. 15 S., R. 12 W., sandstone No. 6 is exposed at the top of the creek bluff, and below it is about 9 feet of dark bluish brown, fissile, clayey shale which probably marks the horizon of the coal described above. Half a mile farther north a massive, medium-grained layer of sandstone 5 feet thick has been quarried at two places a few feet above the stream. This bed was not clearly identified but it seems to be either sandstone No. 4 or No. 6 of the Deadwater section. It is exposed in the road opposite a house about ⅛ mile farther north, where it dips at a high angle to the northeast. On the east side of the valley this sandstone is again exposed with a N-N. E. dip of probably 60 or 70 degrees. These exposures are too small to be of much structural value. They probably mark a slight fault or sharp buckle in the surface beds.

Small exposures of shale and thin interbedded sandstone occur along this valley to the southern edge of Sec. 25, but above that point the Pottsville rocks are concealed by Cretaceous sand.

Along the railroad through the northern part of Sec. 1 the cliff-making beds Nos. 4 and 6 are almost continuously exposed. They are here thin-bedded, compact, greenish, shaley sandstones with occasional thicker layers of purer sandstone. North of Stough, in the S. E. ¼, Sec. 36 and the western part of Sec. 31, the sandstones are generally thin-bedded and poorly exposed, but they have been quarried in a small way at one or two places. These quarries appear to be on sandstone No. 4 of the Deadwater section. Northward through Sec. 31 and as far as the center of Sec. 30 sandstone is well exposed at many places along the sides of the valley. In the latter locality, where the Pottsville rocks disappear beneath the Cretaceous sand, a massive yellowish sandstone having much the appearance of No. 8 of the Deadwater section is exposed in the bank of the creek, above a few feet of dark bluish-brown shale. This may be, however, a locally massive phase of sandstone No. 6. A close correlation of the sandstone ledges along this creek is very difficult because of their variability.

Sandstone and shale are exposed on both sides of Box's Valley, through Sec. 2, T. 16 S., R. 12 W., from the coal outcrop described above, and on the south side of the valley in the northern part of Sec. 11. The writer is not certain of the identification of the massive sandstone ledge at the top of the cliff on the south side of Box's Creek in the southeastern part of Sec. 2. It is either sandstone No. 4 or No. 2 of the Deadwater section. It seems more probably a local thickening of No. 2. The sandstone exposed at the above locality is more or less massive to a short distance south of Sec. 2 where it changes within 150 yards to yellowish brown sandy shale and thin smooth-bedded sandstone, and farther along this outcrop in the N. E. ¼, Sec. 11, the sandstone bed known as No. 4 of the Deadwater section is quarried at a number of places. This group of cliff-making sandstone beds is exposed in the road at the foot of the hill in the southern part of Sec. 2. Sandstone No. 2 also disappears below Cretaceous wash in the N. W. ¼, S. W. ¼, S. W. ¼, Sec. 2, but it has been quarried a short distance to the west of this place. Between this outcrop and Gas Wells Station no outcrops of Pottsville beds were seen on the north side of Box's Creek. On the south side of the valley these beds are concealed by the Cretaceous to about ¼ mile west of Sipsey Station, where a small exposure of shale with some shaly interbedded sandstone occurs along the creek bank for about ¼ mile. A similar exposure of shale occurs on the west side of the tributary to Box's Creek from the south which enters Sec. 9 at the southeast corner. This exposure extends more than half way across the southern portion of Sec. 9 from the southwest corner and consists of a few feet of brown to greenish sandy shale and thin layers of sandstone. except near the western end where 10 feet of massive greenish irregular-bedded sandstone is exposed in the creek bluff. This sandstone is also exposed on the opposite side of the valley at Gas Wells Station. These exposures are such as to leave doubt as to the proper correlation of this sandstone with the beds described above. In general appearance it resembles both sandstone No. 8 and sandstone No. 2 of the Deadwater section, but from the general dip shown by the exposures along Box's Creek in Sects. 9 and 10 the writer thinks that it is most likely the latter. He is fully aware that such a correlation is extremely hazardous when based solely on a hurried examination of the exposures found between this place and the type locality of the Deadwater section, and he therefore in no sense considers such a correlation final until it is supported by a more thorough field examination and by sufficient paleontological data to clearly establish the age of these beds.

If the above correlation proves to be correct, the 90 feet of sandstone and sandy shale found below the alluvium in Providence well No. 1 (Well section G, Pl. II in pocket) is the prominent sandstone described above as containing the cliff-making beds 2 to 8, inclusive, of the Deadwater section. The coal bed which is reported in the shale overlying this sandstone in Providence well No. 6 (section H, Pl. II in pocket) correlated above with the Brookwood Coal, is probably equivalent to the coal described as outcropping in the spring in the central part of the N. E. ¼, S. E. ¼, Sec. 28, T. 15 S., R. 11 W..

Exposures of Pottsville rocks along Sipsey River.—Along Sipsey Valley within the area mapped the exposures of Pottsville beds are confined to a small outcrop of sandstone and shale in the road ¼ mile north of Gas Wells Station. A small outcrop of massive sandstone with some shale is shown in the river bluff at and for about one-third of a mile south of Newton's Mill; and a similar exposure appears along the river bluff farther north in Sects. 28 and 33. The sandstone seen in the road north of Gas Wells Station is the same as that in the railroad cut at this place. At Newton's Mill twenty feet of massive sandstone outcrops above river level. The upper part of this bed is a coarse light to yellowish massive sandstone which appears to be the same as that at Gas Wells. A fault with a general northwest-southeast trend is shown at this mill, but north of it for almost a mile the Pottsville rocks are not exposed.

At a place where Sipsey River washes the base of the hills about ¾ mile north of Newton's Mill, alternating layers of brown sandy shale and thin shaly sandstone are exposed which have a slight dip upstream. From this place northward along the base of the hills similar beds are sparingly exposed. At the point where the line between Sects. 28 and 33 cuts the base of the hills, a massive cliff-making sandstone is well exposed showing a fault, striking about N. 45° W., with the downthrow to the southwest, the displacement being 40 feet or less. This appears to be sandstone No. 2 of the Deadwater section. Northward from this place the sandstone dips gently upstream and soon disappears below valley level.

EXPOSURES OF CRETACEOUS AND YOUNGER BEDS IN THE FAYETTE DISTRICT.

As the object of this examination was to determine the conditions under which gas has accumulated in the Carboniferous rocks, little attention was given to the Cretaceous and younger beds which overlie the gas-bearing formation unconformably, and which are of no value in attempts to determine the dip of the gas-bearing beds. On the map the exposed areas of Cretaceous and Tertiary beds are shown by the green tint. These rocks are composed of unconsolidated sand and clay with some beds of dark red conglomerate and coarse red sandstone cemented by iron. The valleys are covered by superficial beds of wash and alluvium of Recent age, deposited by the present streams.

STRUCTURE.

GENERAL STRUCTURE OF THE REGION SURROUNDING THE FAYETTE GAS FIELD.

The general structure of the Warrior coal basin, in which the Fayette gas field occurs, is that of a broad, flat basin, gently tipped to the southwest, with the strata steeply upturned and faulted at the eastern edge along Birmingham and Sequatchie valleys and the western limb hidden beneath the unconformable Cretaceous beds. The most prominent structural feature in this basin is the Sequatchie anticline (Pl. I). This fold is highest at the northeast border in Blount County, and pitches southwest to the northern part of Tuscaloosa County, where it flattens out and loses its prominence. Between this anticline and Birmingham Valley the rocks though generally synclinal in structure are wrinkled into many minor folds and in places are cut by many faults.

West of Sequatchie anticline the rocks are less disturbed and no large, well-defined folds have been discovered, though the area seems to have been subjected to enough deformation to slightly wrinkle the strata into many low irregular folds and in some places to produce local faults of slight displacement. The structure of the Warrior basin has not been studied in sufficient detail so that the positions of all minor folds have not been traced out and mapped.

On Plate I the general structure of the basin is suggested by the lines marking the outcrops between the formations noted thereon. The direction of the line of contact between the Pennsylvanian and Mississippian rocks shown on the map from the western border of the State is almost due east to the southeastern part of Morgan County, from which it bends sharply to the northeast to Tennessee River. This line is seen to be roughly parallel to the outcrop of the Bangor limestone which marks the northern edge of that part of the Mississippian series shown on the map. This change in direction of the line of outcrop seems to be due to a broad doming of the strata north of Tennessee River along a line passing near the towns of Athens and Decatur from which a broad anticline trends along southward through the western part of Morgan and the eastern part of Winston counties. The effect of this fold is noted in the curve in the outcrop of the Black Creek coal bed in northern Walker County, as shown by the dotted line on Plate I. The direction of the line of outcrop of this coal is northeast to the bottom of the syncline west of the Sequatchie anticline; thence southward along the western limb of this fold crossing the axis near Quinton in the northwestern part of Jefferson County, from which it bends again toward the northeast to the axis of the syncline on the east side of the Sequatchie anticline, from which it again trends in a southern direction to the edge of Birmingham Valley north of that city. There is evidently a well-defined synclinal area a short distance west of and parallel to the Sequatchie anticline throughout its entire length, but the details of the structural features in and west of this area are not known, except in a portion of the Fayette district which is described below.

The folds in the Warrior field which have a general northeast-southwest trend were formed during a period of great crustal movements when very intense folding and large thrust faults were produced along the Appalachian Mountains from middle Alabama to the State of New York. In Alabama this belt of intense folding and faulting lies east of the Warrior coal field. The impulse which produced this deformation came from the southeast and most of its energy was expended before reaching the Warrior field. The Sequatchie anticline is the most northwestern fold of prominence that was developed by this movement. Westward from it strata originally horizontal were more or less wrinkled into a series of broad, open, irregular folds, having a general northeast-southwest trend.

Another period of deformation in portions of the Warrior coal field was marked by the depression of the region to the west of it along an axis parallel to the present course of Mississippi River below its juncture with the Ohio. This sinking was followed by an encroachment of the sea in which the Cretaceous and Tertiary sediments were laid down. This regional depression may have produced more or less deformation in the Warrior field, the folds having a general northwest-southeast trend. These two great crustal movements are responsible for the structural features in the Fayette district.

STRUCTURE OF THE CARBONIFEROUS ROCKS OF THE FAYETTE DISTRICT.

GENERAL STATEMENT.

On the map (in pocket) an attempt has been made to show the dip of the Carboniferous strata in portions of the Fayette district by the use of the contour lines printed in brown. These contours are lines of equal level with a vertical interval of 10 feet and are numbered according to their height in feet above sea level. They are drawn upon the horizon of the coal bed described in the Clear Creek and Deadwater sections in the chapter on "Areal distribution and character of outcropping beds." For example, the heavy brown contour line marked 350 is drawn through all points supposed to be on the horizon of this coal bed that are 350 feet above sea; the next brown line on one side of it marks all points on this coal that are 340 feet above sea, and the one on the opposite side marks the points at which the coal is 360 feet above sea level.

Accuracy of the structural contours.—The accuracy with which structural contours may be drawn upon any deformed surface depends, of course, upon the number and position of the points at surface whose actual elevation above sea level has been determined by instrumental work in the field; and this in turn depends upon the position and extent of the outcrop of the bed upon which the measurements are taken. Unfortunately, in the Fayette district the coal bed upon which the structural contours are based is exposed at not more than four places, so far as the writer is aware. In order partially to avoid the difficulties of contouring a bed which is so rarely exposed, the writer has used the approximate vertical distance between this bed and the tops of the cliff-making sandstone beds described in the chapter on "Areal distribution and character of the outcropping rock," and used these vertical distances to calculate the height of the horizon of the coal at places where it is not exposed or could not be found. In this way all of the measurements secured upon recognized beds were reduced to approximate elevations of the coal bed and from these elevations and the known dip of the exposed beds, the contours were drawn.

By the method just described it will be seen that the structure or 'lay" of any bed that is well exposed can be determined very accurately. From these facts and the data set forth in the chapter on "Areal distribution and character of the outcropping rocks" the reader can readily see that though the contours on the map in the main show the structure fairly accurately, they may be considerably in error locally because of the lack of accurate measurements on the key surface.

In places on the map where no contours are drawn, the surface is covered by Cretaceous and younger beds which prevent accurate measurements on the coal. The structure of the Carboniferous rocks in this part of the district is unknown and cannot be determined accurately until a sufficient number of wells have been drilled which will furnish accurate measurements to some recognizable bed. This statement applies equally well to any part of the Gulf Coastal Plain in Alabama, where the Carboniferous beds are concealed beneath Cretaceous and younger sediments.

In places where the structure contours are solid lines positive elevations obtained on recognizable beds are sufficiently numerous to warrant the assumption that they are approximately correct. The broken contours while based upon some accurate data may be in considerable error. The accuracy of those contours that bear interrogation marks is in doubt. Care should be taken in using these contours to give due allowance for errors that are likely to creep into work based on insufficient data or on data not known to be accurate.

STRUCTURAL FEATURES IN THE CARBONIFEROUS STRATA.

The structural contours on the map show clearly that the deformation in the Carboniferous beds of this particular area has been relatively slight, and that the beds lie in broad, open, irregular folds, having a trend generally northwest, southeast in the eastern part of the mapped area and probably a more east-west trend farther west.

The principal structural features, partially brought out by the contours on the east side of the map, are the belts of relatively rapid southwest dip. One of these belts passes through the eastern parts of secs. 28 and 33 and the western parts of Sects. 27 and 34, T. 15 S., R. 11 W., and continues southeastward through Sects. 3, 2, and 11, T. 15 S., R. 11 W. Southwest of this belt of relatively steep dip is a shallow syncline, the bottom of which passes through the central part of Sects. 29 and 33, T. 15 S., R. 11 W., and Sects. 3, 10, 14, 15, and 23, T. 16 S., R. 11 W. Southwest of this trough the rocks appear to rise gently to the axis of a very low broad anticline which appears to pass through Sects. 3, 29, and 32, T. 15 S., R. 11 W., and Sects. 4, 10, 15, 22 and 27, T. 16 S., R. 11 W.

Southwest of this anticline the Cretaceous sand obscures the structure and it cannot be determined with any degree of certainty except in portions of Secs. 4, 9, 10, 15 and 16, T. 16 S., R. 11 W., where the steep dip of the rocks discloses what appears to be the eastern end of a syncline of considerable magnitude, pitching west-northwest under the Cretaceous beds. The lowest portion of this trough probably has not been contoured, but in the southeast corner of Sec. 9, the key surface is at least 200 feet lower than it is in the central part of Sec. 35, T. 16 S., R. 11 W. There may be faults in this area which render the observed dips misleading, but no direct evidence of a fault was seen in the field.

On Box's Creek no well defined fold is revealed by the structure contours in the area of Carboniferous rocks exposed. The very gentle dip toward the south and southwest appears to be interrupted by a shallow syncline passing through Secs. 1 and 2, T. 16 S., R. 12 W., and by another small syncline, the beginning of which is shown at the southeast corner of Sec. 35.

Local buckles (small anticlines).— In the southwest part of Sec. 1, T. 16 S., R. 12 W., there is evidence of a small anticline, of a very small extent, which brings the exposed Pottsville sandstones up into a very sharp fold, having a general northeast-southwest trend, with dips of 40 to 80 degrees, but with a total width of only a few feet. This type of structure is apparently very common to this region. On the road in the southern part of the NE ¼, NE ¼, Sec. 11, T. 16 S., R. 12 W., a similar buckle brings the Pottsville sandstone up at an angle of 50° to 70°. Two other buckles of only a few feet in width are finely exposed on the Fayette-Bankston road in the N. E. ¼, N. W. ¼, Sec. 1, T. 16 S., R. 12 W. These appear to have a northwest-southeast trend. Another of these local buckles occurs on the road near the western edge of the N. W. ¼, N. W. ¼, Sec. 36, T. 15 S., R. 12 W. Others of less magnitude were seen, but as these miniature anticlines were probably formed by local compression due to the subsequent wrinkling of slightly folded beds across the major folds they are probably very local features that extend only to shallow depths.

Faults.—Few faults occur in the area mapped and these appear to be confined entirely to breaks in the strata due to tension. They seem to be very local in extent and to show small vertical displacements. One of these faults is exposed on the road leading southeast from Cotton's Mill in the N. E. ¼, S. E. ¼, Sec. 33, T. 15 S., R. 11 W. Here the downthrow appears to be to the north and the displacement is probably between 40 and 50 feet. The trend of this fault seems to be northwest-southeast.

Another fault is thought to occur on Rock Creek about ¼ mile west of the road crossing in Sec. 27, T. 16 S., R. 11 W. Here the Pottsville sandstones suddenly disappear and are succeeded upstream by dark bluish-brown, sandy shale, which resembles closely beds of shale lying from 40 to 80 feet below the sandstone. If these identifications are correct the fault has an almost north-south trend with the downthrow to the east.

At Newton's Mill in the southern part of Sec. 33, a well marked fault occurs with a general northwest-southeast trend. However, the lack of good exposures at this place leaves the writer somewhat in doubt as to the character of this fault. It may either have a displacement of 70 or 80 feet with the downthrow to the southwest or the downthrow may be to the northeast with 20 or 30 feet displacement.

One mile north of Newton's Mill, near the northeast corner of Sec. 33, a fault is exposed in the bluff at the foot of the river hill. This fault has a displacement of less than 40 feet, the downthrow being to the southwest.

In the core drill hole of the Cosmos Oil and Gas Company (Section E, Plate II in pocket) the black shale No. 16 shows many slickensided surfaces which suggest faulting, but other evidence of a fault at this place is obscured by wash of Cretaceous debris which hides the Carboniferous rocks.

The faults in the Fayette district are probably due to differential tension developed locally by the subsequent wrinkling of slightly folded strata almost at right angles to the folds. This subsequent wrinkling was apparently so slight that faults of very local extent only could have been developed. The depths to which displacements of strata extend along these fault is, of course, unknown. However, because of the slight amount of folding, the local nature of the tension thus developed, and the predominance of soft yielding shale below the surface, it seems reasonable to assume that the depths to which the displacement may extend is relatively very small.

Structure of the Fayette gas field.—The available data relative to the structure of the Fayette gas sand in and surrounding the gas field, are too meager to justify an attempt to draw structure contours on this bed. Therefore, instead of contours to show the structure of the sand, the altitude of the mouths of the wells and the depths to the gas sand in each are shown on Plate II. From these figures the depth of the gas-bearing sand below sea level can be easily calculated.

No records of wells Nos. N, P, R, S, T, and U were obtained, and the Fayette gas sand is not shown in well sections C and D. In all of these wells a sandstone near the top has been correlated with the massive sandstone which is exposed at Newton's Mill, at Gas Wells Station, and on the south side of Box's Creek southeast of this station. As already stated, this sandstone is believed to be the upper sandstone No. 2 of the Deadwater section which is exposed up Box's Creek' and in the eastern part of the area mapped. Altitudes obtained on this bed have been reduced to equivalent ones on the coal used as a key stratum, and contours drawn to show the approximate dip of the key rock in the gas field, in order to give some idea of the structure. These contours are printed on the map in brown. With these few facts as a basis for deductions Figures 1 and 2 were drawn as mere guesses at what the structure may be found to be when future drilling has furnished sufficient data to enable the contours to be drawn accurately. In addition to these two figures the imagination of the reader can supply many different ones which may be drawn without contradicting any of the facts, now known, regarding the dip of the beds in this vicinity.

In figure 1 the position of the Fayette gas field is assumed to be on the west side of a pitching anticline having a general north-northeast-south-southwest trend. The flat-topped crest of this fold occupies the eastern part of Sec. 9 and the western third of Sec. 10, from which the rocks rise northward along the axis of this fold. In this sketch the position of the fold is based upon the negative fact that there is nothing available to show that the sandstone outcropping at Newton's Mill and dipping southward does not have a continuous dip from that point to its next exposure on the road near well E; and that the sandstone found near the top of well D is the same bed. In drawing these contours the assumption is made that a shallow syncline crosses Box's Valley from north to south in the vicinity of Sipsey Station, and that to this trough is due the fact that here are found no exposures of the sandstones which outcrop farther up the valley. The apparently slight dip of the beds down stream in the S. E. ¼, Sec. 9 suggests that the axis of this fold may trend almost north and south in the western part of Sec. 10. The syncline shown as passing southwestward through Sections 4 and 8 is assumed to exist because the apparently steep dip between wells L and K suggests that the strike of the beds is at right angles to the line connecting these wells; and that if this is true the contours must make a sharp bend in passing northward from the gas field. The contours in the gas field proper

FIG. 1

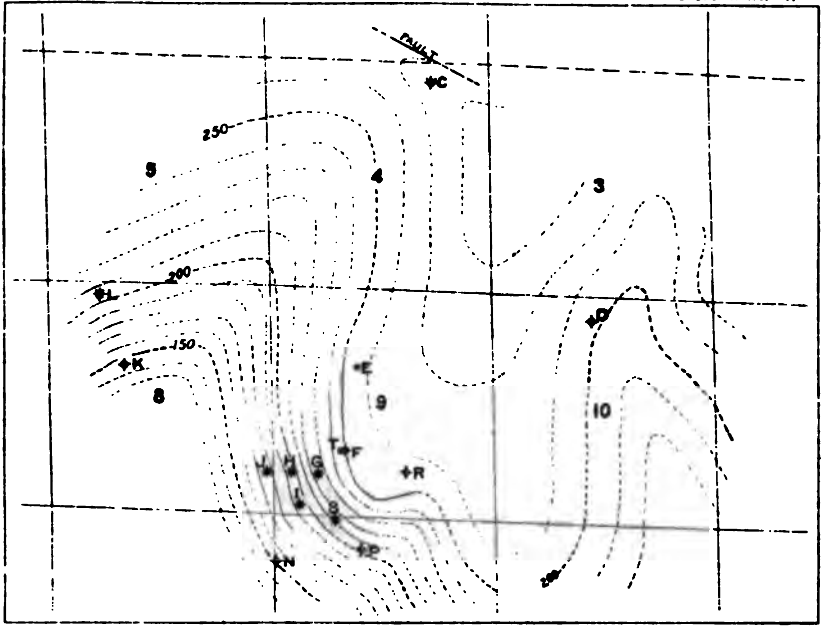
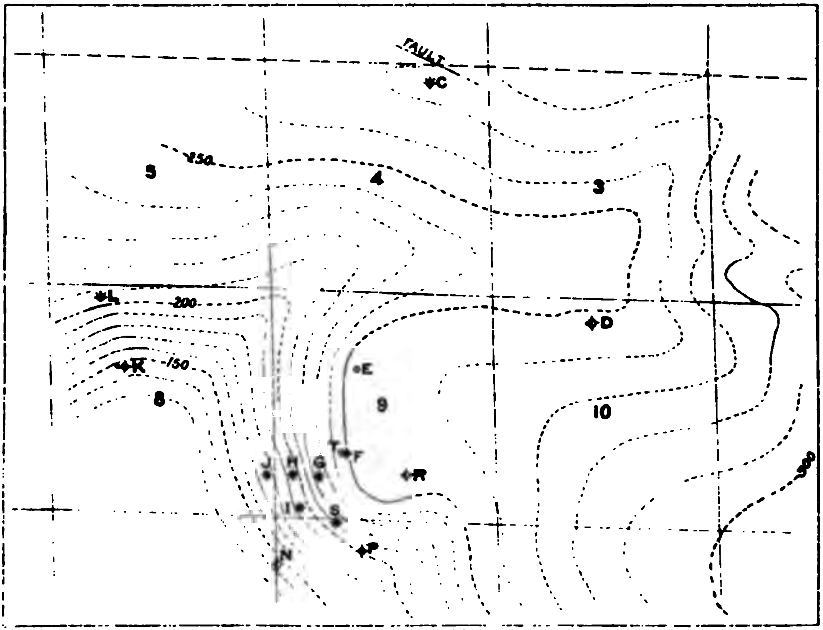


FIG. 2



DEEP WELL SYMBOLS

● GAS ◆ SHOW OF OIL AND GAS ✱ SHOW OF GAS ✱ SHOW OF GAS (WELL UNFINISHED)

◆ UNPRODUCTIVE EXCEPTING SLIGHT SHOWS ● CORE-DRILL HOLE ◆ REPORTED UNFINISHED AND UNPRODUCTIVE

Figs. 1 and 2.—SKETCH MAP OF THE FAYETTE GAS FIELD AND VICINI

Showing two of the many possible guesses as to the structure of the r in this area *which may be* made from the available geologic data.

are based on estimated altitudes of the top of the base of the sandstone near the top of the wells and are therefore probably nearly correct.

In Figure 2 the contours are drawn upon the same surface and are based on the same facts as in Fig. 1, but these data are given a different interpretation. In this case the fact that the sandstone at Newton's Mill has a much greater dip at the point where it disappears beneath the Cretaceous cover, ¼ mile south of well C, than would be necessary to give it an even dip from this point to its next exposure near well E, suggests that a shallow trough occurs in the rocks between these two wells. This assumption is strengthened by the fact that no exposures of the sandstone could be found along the base of the river hill between the outcrops near wells C and E on this bed; therefore, it may be below valley level. The assumption of a syncline between wells C and E is also suggested by the fact that a change in the direction of the dip very probably occurs between wells E and K, and the resulting syncline might easily extend northeast into Sec. 3. If this is true the axis of the trough probably passes east of well D, and from it the beds rise gently toward the north, south, and east. This syncline would be a continuation of the one shown on the map in Sections 1 and 2, T. 16 S., R. 12 W.

These two sketches suggest that others might be drawn without contradicting any of the known facts regarding the structure. For instance, the shallow syncline shown in Figure 1 as having a north-south trend through Sec. 10 could be added with a slight modification to Fig. 2, without conflicting with any facts at present recognizable regarding the dip of the Pottsville beds in this locality; also because of the slickensides in shale bed No. 16 of well section E (Pl. II) a fault may be assumed to pass through this well with a northwest-southeast trend, thus changing entirely the local structure. There seems to be little question, however, that the Fayette gas field, as developed by the wells shown on the map, is located at a point where the rocks dip relatively steeply toward the south or southwest.

Economic Features of the Fayette District.

TESTS FOR OIL AND GAS IN THE FAYETTE DISTRICT.

As stated in the beginning of this paper, drilling in the Fayette district has resulted in the finding of gas in considerable quantities in Providence wells Nos. 1, 6, 8, 9, and 10. These wells are marked on the map by the letters G, I, H, S, and J, respectively. Nos. 9 and 10 (S and J) have shown more or less salt water, and the latter is said to have been badly damaged by injudicious shooting. The writer was given no records of Providence wells Nos. 11, 12, and 13 (R, P, and U) or any direct evidence as to their depth and the nature of the rocks encountered in them. So far as he knows they may or may not have been drilled to the Fayette gas sand. None of them shows oil or gas in paying quantities. Providence well No. 5 (F) is said to have been drilled first to about 1690 feet and later deepened to over 2200 feet. No record of the second drilling could be obtained. The bottom portion of the records of Providence wells Nos. 2 and 4 (D and C) which would be of greatest value are not given (See Plate II). The only positive data regarding the character of the gas sand in the immediate vicinity of the producing area are given in Providence wells Nos. 3 and 5 (L and F) and in the Fayette Gas Company well No. 1 (K), the records of which are shown on Plate II. These three wells have undoubtedly passed through the Fayette gas sand without finding gas in paying quantities. A well was also started about 4½ miles northwest of Fayette by the Providence Oil and Gas Company, but it is said to have been abandoned after being sunk to a depth of a few hundred feet. The well (M) of the Fayette Gas Company, situated 3 miles southwest of Kennedy, has not been completed at this writing, and no data regarding it are available, other than that given on Plate II.

The Woods well No. 1 (B) of the Alabama Central Oil and Gas Company, located on the railroad about 1½ miles west of Bankston, passed through the Fayette gas sand between 1350 and 1440 finding a slight "show" of oil and a little gas. Small "shows" of oil and gas were noted at many places in the Freeman well No. 1 (A), but at no horizon was it found in paying quantities*. The well (U) at Bankston was drilled to a depth of about 800 feet by the Providence Oil and Gas Company and work on it suspended during the time the writer was in the field. Slight "shows" of oil and gas are reported from it.*

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*See Appendix, page 66.

A well is being drilled by the Five Rivers Oil and Gas Company near Newtonville about 13 miles south of Fayette, but up to the present date neither oil nor gas in paying quantities have been reported from it. Another deep well was started near Reform about 25 miles southwest of Fayette, but no data relative to it is at hand. A derrick was built near Berry about 18 miles east of Fayette, but no drilling had been done here at the time field work in this district was closed.

Summing up the situation; the developed part of the Fayette gas pool is about 2,500 feet long by 1,000 feet wide and contains five producing wells with initial capacities ranging from probably 250,000 to 4,500,000 cubic feet per day. One of these wells (Providence No. 8, (H) supplies the town of Fayette with gas. The others are closed. The eight other wells drilled in search of gas within 2 miles of this pool and the six other holes drilled in the region have reported neither gas nor oil in paying quantities.

FUTURE PROSPECTING IN WESTERN ALABAMA.

The following questions probably cover the crux of the oil and gas situation in Western Alabama from a commercial viewpoint.

(1) Is the Fayette gas pool fully outlined by the wells already drilled?

(2) From the indications shown by developments to date are pools of oil and gas likely to be found in the Warrior coal field and adjacent localities in the Gulf Coastal Plain?

(3) If the Warrior coal field offers favorable inducements for testing, where should the test wells be located?

The remaining pages of this report will be devoted to an attempt to answer these questions so far as the limited data available permit.

PROBABLE EXTENT OF THE FAYETTE GAS POOL.

In answer to the first question, the Fayette gas pool does not appear to be fully developed, though it very probably is not a large pool. There is no evidence available to show that a well located 800 or 1,000 feet due north of Providence well No. 8 (H) should not get gas, (*) and if this one should prove successful, gas or oil may reasonably be expected in other wells drilled along the strike of the rocks in this direction to beyond the Fayette-Sipsey road. The Cosmos well No. 1 (E) is favorably located for either oil or gas if the Fayette gas sand is soft and porous at this point. To the east, southeast, and south of the producing area Providence wells Nos. 11, 12, and 13 (R, P, and N) seem to mark strategic positions for tests. If these have all found the Fayette gas sand unproductive, the limit of the pool in that direction appears to have been reached unless a well located about 800 feet north of No. 9 (S) and the same distance southeast of No. 1 (G) should find a good quality of gas sand, in which case it may be productive. If this well should prove to be successful, a well located midway between Providence wells 11 and 12 (R and P) would have a chance for either oil or gas in paying quantities. Assuming the Fayette gas sand to be uniformly good over this area and that Providence wells 11, 12, and 13 have not been drilled to it, No. 11 (R) probably offers the best chances. No. 12 (P) seems less favorably located and the position of No. 13 (N) appears to be unfavorable. The latter will most likely furnish salt water from the gas sand. The wells R and E, when finished to the gas sand, should go far towards determining the extent of this pool, since, from structural indications, the area northeast of the producing wells is the most favorable. The prospects for an extension in this direction are greatly depreciated, however, by the failure of Providence well No. 5 (F) to find gas. This failure may have been due to a locally poor sand which, if soft and porous farther northeast, may again become productive. If either wells R or E should prove to be productive a well located 2,000 feet a little south of east of well E and the same distance from well R should go far towards determining the extent of the pool. Providence well No. 4 (C) should be drilled deeper as a test towards the north.

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*See Appendix, page 66.

In brief the Fayette gas pool is probably not fully developed. The most favorable direction for its extension is toward the north from Providence wells Nos. 1 and 8 (G and H) and, if the unfinished well E is successful, the trend of development should be east as well as north. The writer doubts, however, if this pool will be found to be a large one, especially if Providence wells Nos. 2 and 11 (D and R) have reached the Fayette gas sand.

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*See Appendix, page 66.

POSSIBILITY OF OIL POOLS OCCURRING IN THE VICINITY OF FAYETTE GAS POOL.

The presence of this gas pool cannot be taken as a sure sign that an accumulation of oil is located somewhere near it. Many large gas fields, without accompanying pools of oil, occur in other parts of the Appalachian region. Most oil pools, however, are accompanied by pools of gas, or else the oil is associated with gas in the same pool. In the Fayette gas pool there is little available evidence to suggest the direction in which a pool of oil is most likely to occur in the gas sand. Such meager data as exist seem to slightly favor the northwest quarter of Sec. 9, and to a much less degree the south half of the S. E. ¼, Sec. 9, and adjoining parts of Sec. 16.

"Shows" of oil and gas have been noted in a number of sandstone beds in the wells of the Fayette district, and it is possible that some of these may be found to contain pools of oil of paying size in this vicinity. The most favorable indications for oil appear to have been found in sandstones relatively near the surface. Of these Nos. 8 and 13 of Section E, Pl. II, appear to be the same sands that carry oil in the Brennen diamond drill hole (T) in the drillers' record of Section F, Pl. II. A study of the core of Cosmos well No. 1 shows that the oil has accumulated in the sandstone as a pool and that it probably only lacks more pressure and a more porous pay sand to furnish wells of commercial size. In a theoretical way the data furnished by this core are intensely interesting. Beginning within No. 5 of this section (E, Pl. II), a bed of dark gray shale is underlain by massive green shale (No. 6) which grades downward into fine greenish, micaceous sandstone (No. 7), which in turn changes abruptly to massive brown (discolored by oil) sandstone (No. 8), saturated with oil, which, sofar as the writer could detect, is of practically the same texture and hardness as No. 7, and is, in fact, a continuation of that bed. This sandstone contains no oil and continues downward unchanged, except for thin sandy shale partings through No. 9. Below No. 9 the sequence described above is repeated, No. 10 being a dark, fine-grained shale, No. 11 a massive greenish shale grading into massive gray, micaceous sandstone (No. 12), and then into a coarser phase of the same bed (No. 13), saturated with oil, with a non-petroliferous sandstone (No. 14) below. A study of this core section leads to the conclusion that these oil horizons represent true accumulations, and that lack of pressure behind the oil, and of porosity in the sandstones in which it occurs, may be the only reasons why they do not furnish oil in commercial quantities. Sandstone No. 8 of this well appears to be a part of the sandstones Nos. 7 to 9, inclusive, of Section L, Plate II, in which good indications of oil were found. These facts suggest that this sandstone is oil-bearing over a considerable area and that in places where it is unusually coarse-grained and porous, small oil wells may be secured.

Another zone which shows more or less oil in almost every well, is marked by No. 22 and No. 24 in Section F, No. 16, Section G, No. 17 Section H, No. 22 Section I, No. 24 Section J, Nos. 17 or 19 Section L, and No. 11 Section M. Similar oil zones may be traced out on Plate II. These general oil zones indicate that the process of accumulation has gone on to a certain extent in this vicinity and also that the Carboniferous strata contain appreciable quantities of oil which at favorable places may have been gathered into valuable pools.

The writer thinks it very probable that other and larger pools of gas and oil exist at places in the Warrior coal field. This belief is based upon the age and character of the rocks which underlie this territory within reach of the drill. From these formations have been secured a large part of the oil and gas of Oklahoma, much of that of West Virginia, southeastern Ohio and portions of Pennsylvania. The general structure of the coal basin and the detailed structure, as shown by the small area mapped, apparently is as favorable as that of the great oil and gas regions mentioned above, with the possible exception that there may be too many faults in certain parts of the Warrior coal field to offer ideal conditions. From the scanty data available it seems that the general underground water conditions are such as to offer almost ideal opportunities for this most important factor of accumulation to exercise its function. These facts, taken in connection with the known existence of one gas pool (though it may be a small one) and the presence of more or less gas and oil in sandstones at a number of points (indicating that the rocks have an appreciable amount of these hydro-carbons scattered through them) seem to show that all of the general geologic conditions considered essential for the formation of valuable accumulations of oil and gas are present in this region.

FAVORABLE AREAS FOR TESTING OUTSIDE OF THE FAYETTE FIELD.

With but a very limited amount of data at hand relative to the age and character of the unexposed rocks of this region in which oil and gas pools might occur, and still fewer facts regarding underground water conditions, together with the lack of a map of the Warrior coal basin showing in detail the structure of the rocks, it is impossible to pick out with confidence small areas that are especially favorable places for testing. The area in which the structure of the rocks is shown on the topographic map, though large enough to indicate the character of the folds to be found in this region, is far too small to be of most value in determining the best places for future drilling in a prospective oil and gas territory as large as the Warrior coal field.

Gas in paying quantities has been found only in the Fayette field where it comes from a sandstone in the lower part of Pottsville formation. The few wells that have been drilled below this sand, though unproductive, can in no sense be considered as serious evidence against the possibility of valuable pools existing in the Mississippian series and even lower formations. If the oil and gas of this region have been subjected to the same general processes of accumulation as that of the Appalachian region farther north in New York, Pennsylvania, Ohio, and West Virginia, the accumulations in the upper sands will be found at places where those beds lie at a lower level than where the deeper horizons are productive. Therefore, if it is assumed that the Fayette gas sand is near the middle of the vertical section of oil and gas-bearing beds of this region, we should expect to find that the sands above this bed, which show oil and gas in the Fayette field, will contain the largest number of paying pools at places where they are at a lower level, or toward the south and west. Conversely, if the Mississippian series or any lower formations are productive, the pools are more likely to be found at points where they are at as high, or a higher, level than they are in the Fayette field, especially if upon deeper drilling in the Fayette field these lower beds are found to be not productive and to furnish little or no salt water.

From this it is clear that there is absolutely no way of determining where drilling should be done until a detailed map showing the dip of the rocks over a considerable portion of the Warrior coal basin is available for study. With such a map and facts regarding the underground water conditions in a number of widely scattered deep wells of this region, the uncertainty regarding the best localities for testing would disappear. It is, therefore, highly important, from a business as well as a scientific point of view, not only that the geology of this region should be thoroughly studied, but also that the greatest care should be taken in future deep drilling to find out and record the water conditions of the beds. The kind of rock in which water is found, the kind of water, whether fresh or salt, the height to which it rises in the well, and its relative volume, are facts of prime importance in selecting those areas in which valuable pools of oil and gas are most likely to occur. In using this data the geologist bases his deductions upon the unquestioned laws of cause and effect, which have been more clearly worked out in other oil and gas fields that have been thoroughly developed. Such deductions, though based upon imperfect data in a new field (and therefore not unquestionable) when consistently followed, will always eliminate a greater or less percentage of the element of chance which is present, and which will probably always be present in oil and gas operations.

With the above limitations before the reader, the writer ventures to suggest that the area lying north of the Fayette district (Plate I) has not received the attention from drillers that it deserves; though in making this suggestion he does not wish to depreciate the value of testing in other directions.

From what is at present known of the geologic conditions of this region, it seems probable that the northern part of Fayette County, the western part of Walker, the eastern part of Lamar, and all, or at least the southern portion of Marion, and the western part of Winston counties contain small areas in which all the conditions necessary to the occurrence of oil and gas are present.

This suggestion is advanced in the hope that future wildcat drilling will be more evenly distributed over the western part of the Warrior field and adjacent parts of the Coastal Plain. Such testing will not only more quickly determine the value of this region for oil and gas, but will also furnish very valuable geologic data which may be used to great advantage in restricting the areas that are worthy of thorough testing.

APPENDIX.

Page 58. a. The writer has been informed by Mr. H. G. May, superintendent of the Alabama Central Oil and Gas Company at Bankston, Alabama, that this well was drilled later to a depth of 2,932 feet without encountering oil or gas in commercial quantities, but no detailed record of the well other than that given on Plate II has been obtained.

Page 59. b. This well at Bankston station, which is Providence well No. 13, was later drilled to a depth of about 1,700 feet where a large quantity of salt water was encountered in what is thought to be the Fayette gas sand, and operations were temporarily suspended. Still later, drilling was resumed and a total depth of 2,050 feet reached. On June 22, 1911, gas was encountered in this well while drilling at a depth of about 2,050 feet, the hole being at that time filled with several hundred feet of water. The writer has been informed by Mr. James L. Davidson of Birmingham and Mr. H. G. May of Bankston that this well furnished a strong flow of gas with an estimated pressure of possibly as much as 800 pounds. Mr. Davidson guessed the flow at about 6,000,000 feet per day, but owing to the fact that the well stood at the last account with 2,000 feet of water in the hole, no definite figures have been obtained regarding the value of this find. Mr. Robertson of the Providence Oil and Gas Company expressed the belief that when the water has been successfully shut out of this well it will furnish gas in commercial quantities.

Page 60. c. The writer has been informed that a well has since been drilled at this location which has furnished gas in commercial quantities. He is not aware of other developments in this vicinity.

[illegible]

ALABAMA

[illegible]

GEOLOGICAL SURVEY OF ALABAMA
EUGENE ALLEN SMITH, Ph. D., State Geologist

BULLETIN No. 11

Roads and Road Materials of Alabama

By
Wm. F. PROUTY, Ph. D.
Chief Assistant

MONTGOMERY, ALABAMA
THE BROWN PRINTING COMPANY, PRINTERS AND BINDER
1911

University, Ala., July 10, 1911.

HON. EMMET O'NEAL,
Governor of Alabama,
Montgomery, Alabama.

Sir:—

I have the honor respectfully to transmit herewith a report on Roads and Road Materials in Alabama by Dr. William F. Prouty, Chief Assistant, with the recommendation that it be published as Bulletin No. 11 of the Alabama Geological Survey.

Very respectfully yours,
EUGENE A. SMITH,
State Geologist.

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PREFACE.

Every publication should justify its being by some good return to those who take the time to look through its pages. The purpose of this bulletin is to stimulate an interest in the building of good roads and to serve as a guide to those who are actually engaged in the construction or maintenance of roads. In the compilation of the various articles from different authors, it has been the purpose to keep the volume as far as possible of a practical nature. The appendix contains information of various kinds which it is thought will be the most helpful to those using the volume.

Due to limited space the subjects treated are necessarily not exhaustive in their character, but they will be found to give the general principles and will serve as general guides. It may be noted that the articles deal with the country and suburban highways rather than city streets, for it is upon the former class of roads that the largest amount of money is spent, and the poorest results obtained. Most towns and large cities have skilled overseers and engineers to have charge of construction and maintenance work. It is evident throughout all the discussions in the bulletin that one of the greatest needs in the construction of good roads is competent engineers to have charge of the work. It is further evident that such engineers would save thousands of dollars to the tax payers and at the same time would give us far better roads.

One of the greatest drawbacks to good roads, in spite of all that has been said against it in recent years, is the perpetuation in many places of the statute labor system. In the election of commissioners and overseers it often happens also that popularity and political pull are too often the ruling factors rather than real fitness.

The Office of Public Roads at Washington and many of the leading universities of the country are now offering Road Engineering courses, and I wish to suggest that this branch of engineering offers exceptionally fine opportunities at the present time, to such young men as will fit themselves thoroughly in it.

The creation of the State Highway Commission marks a new era in the progress of Alabama. It is to be expected that from now on economical methods of road construction and maintenance will be much more rapidly adopted, and it is to be hoped that the results of the investigation of the Commission in regard to materials and methods, which will be published from time to time, may prove of some real benefit to the public.

In the preparation of this volume we are greatly indebted to the contributors who have furnished free of cost the articles on the various subjects. We are also indebted to the U. S. Office of Public Roads for considerable information furnished and for co-operative work in compiling the statistical table. We are further under obligation to the various county officers of the State for furnishing statistics concerning their respective counties.

The book has been carefully indexed so that the contents may be made accessible with the least trouble.

ALABAMA ROADS AND HIGHWAYS—AN HISTORICAL INTRODUCTION.

By Dr. Thomas M. Owen, LL. D.

Director of the Alabama State Department of Archives and History, Montgomery, Alabama.

The sketch which follows is an effort, in a very brief way, to indicate the historic origin of Alabama roads and highways. Beginning with an account of aboriginal life, the main Indian highways and trails are discussed, followed by a description of the planting of white settlement, pioneer road beginnings, and early territorial and State road extension. The genesis of the present road laws concludes the introduction. Within the limitations of a preliminary sketch, it is not to be expected that more than a brief outline can be given. While this is true, the facts and conclusions may be relied upon as accurate. In a way the details set forth will form a suggestive basis for more exhaustive and detailed treatment for the future.

Aboriginal Life.

The early explorers of aboriginal America in their ever continuous marches from the seaboard into the interior soon realized that this vast region was not a pathless wilderness. They found the Indians living in villages, subsisting mainly by agriculture, hunting and fishing being only secondary employments to supplement their main food supplies of corn, beans, pumpkins and squashes.

They found the villages, whether contiguous or far apart, connected by trails, and these trails were used by the explorers themselves in their expeditions. In process of time, in the progress of exploration, it was found that Indian America was, in fact, a vast network of such trails, connecting not only village with village of the same tribe, but extending far off to other tribes, so that it was feasible by means of these trails to traverse the entire continent. The trails were always along lines where there were the fewest physical obstacles or obstructions, often going along on the watershed of two streams, when these watersheds pointed in the right direction. The crossing places of streams were always selected with such judgment that from the most remote period down to the present day, these same crossing places have served in numerous instances the purpose of man, whether savage or civilized. The trails also often formed the basis of the modern civilized or white man's road.

The intertribal trails served all the purposes of war and peace. War parties marched along them in their raids against other tribes, in quest of booty and scalps. In times of peace the Indian trafficker slowly toiled along over them laden with his wares to exchange for the wares of another tribe. These intertribal trails thus strongly appeal to the archaeologist, as they were means of a dissemination of relics, which show the wide extent of Indian intertribal traffic.

Relics of Mica have been found in Atlantic States that must have come from a far western region. Sea shells that can only come from the Gulf of Mexico have been found in Ohio mounds. Obsidian relics have been found in Alabama that can only be referred to the Yellowstone region. Relics too of shell have been found in Alabama that show an undoubted intercourse with the prehistoric Shawnees of Cumberland River in Tennessee. White quartz arrow points have been found on a village site in Mississippi that certainly came by tribal traffic from the Indians of Alabama.

An account will now be given of some of the Indian trails of Alabama, the facts given, assembled from acient maps, from ancient books, and from pioneer traditions. This account from the very nature of things is necessarily imperfect, as there can be no doubt that there were numerous other trails, not recorded on maps and in books and not preserved in border tradition. Still the ones that are given will serve to show that the red man of Alabama had a wide intercourse, not only within the bounds of his own tribe, but like the Greek

Ulysses of old, he was often a much traveled man, even in the far distant tribes of the East, North, and West.

SOME INDIAN HIGHWAYS AND TRAILS.

The Great Southern Trading and Migration Trail led from the mouth of St. John's River, Florida, to the mouth of Red River in Louisiana. It crossed the Apalachicola River just below the confluence of the Chattahoochie and Flint, and the Mobile River a few miles above Mobile. It is intimately associated with Mobile Colonial history. Apart from its association with war and traffic, it was the great migration trail used by the Southern Indian tribes and sub-tribes that settled in Louisiana after the fall of French dominion in Mobile.

A trail branched from the great migration trail at the Apalachicola crossing and ran northwest to the Alibamo towns. This trail was the great route of intercommunication between the Creeks and the Seminoles.

A continuation of the Apalachicola-Alibamo trail ran from the lower Coosada towns northwesterly by way of Oo-e-asa to Buttahatchee River and thence continued to the Chickasaw Nation. A Chickasaw Indian traveling this trail would have no difficulty in going to the Coosada and Alibamo towns, and thence to the mouth of St. John's River in Florida.

The Great Pensacola Trading Path, known in pioneer days as the wolf trail, was the most noted trail in Alabama. It led from the Alibamo towns, a group of villages occupying the site of Montgomery, down to Pensacola, and was much used by the Creek Indians, and the traders. By the latter it was enlarged into a horse path, and afterwards it became an American road, much of which is still used. The battle of Burnt Corn occurred on this trail. The present railroad from Montgomery to Pensacola follows closely the lines of the old trail.

A western branch of this trail deflected at Bluff Springs in Escambia county, Florida, and ran northwesterly to the junction of the Alabama and Tombigbee Rivers.

The Mobile Tuckabatchie Trading Path crossed the wolf trail at Flomaton, passed through Brewton, continuing for some distance on the divide between Persimmon and Pigeon Creeks, crossing the latter creek about eight miles southeast of Greenville and thence on to its terminus at Tuckabatchie. The railroad from Mobile to Brewton follows closely the line of the old trading path.

The Big Trading Path, from Mobile to the Choctaw and Chickasaw Nations, ran about a mile west of Citronelle, thence by Isney in Choctaw county and on to Coosha town in Lauderdale county, Mississippi, thence to Plymouth in Lowndes county, Mississippi, thence to the Chickasaw towns. Much of the trading path, then an Indian trail, was traveled by Henri de Tonti in 1702. In American times it became a horse path for traders, afterwards the greater part was used as a post road by the government, and eventually a large part of it was converted into what was known as the Tennessee road.

The Alamuchee-Creek Trail crossed the Tombigbee at the shoals a short distance above the influx of Chickasawbogue in Marengo county. According to local tradition this trail, trending easterly, crossed the Alabama River just below the influx of Cahaba, thence to old Town Creek and thence to the Alibamo towns, the site of modern Montgomery. The part of the trail leading from Montgomery to old Town Creek was certainly the trail traveled by De Soto, and in more recent times a part of the trail formed the basis of the American road leading from Linden to Adams and Martins.

The Great Tombigbee War Crossing was at Black Bluff, Socteloosa, about two miles below the influx of Sukinatcha. Several trails from the Choctaw country converged at this crossing and then continuing as one trail for some distance to the east of the river, where the trail forked, one branch leading to Okfuskee on the Tallapoosa and the other to Coosada on the Alabama. This crossing was greatly used by the Creeks and Choctaws in their wars.

After the surrender of Fort Toulouse, large numbers of Coosadas (Coshattees) and Alibamos settled at Black Bluff, and for some distance thence down the river. At the outbreak of the Creek-Choctaw war of 1766 these Tombigbee settlers received such rough treatment from both belligerents that they returned to their former homes on the Alabama.

The Great Savannah-Mississippi River Trail led from Savannah up to the northern part of Effingham county, thence went west to Tuckabatchie, thence continuing its course to its terminus at Milliken's Bend on the Mississippi—a trail equal in length to the Great Southern Migration Trail.

Two great trails from the east united at Flat Rock in Franklin county, Alabama, and thence continued west to the Chickasaw Nation. One or these trails came from the Chattahoochie to Little Okfuskee thence to Flat Rock. The other, the High Town trail, started from Tellico in Monroe county, East Tennessee, thence southwest to Coosa town, and from it to Flat Rock.

The Great Cumberland River War trail led from the Hickory Ground up the east side of Coosa River up to Turkey town, thence to the well-known Creek crossing on the Tennessee River, near the mouth of Town Creek, above Guntersville, thence to the Cumberland settlements in Tennessee. There were three other crossings on the Tennessee River, one at Guntersville, one two miles below it, and one at Ditto's Landing. But the one near the mouth of Town Creek was the most noted and most used by war parties in their raids against the Cumberland Settlements.

A trail led northwardly from the Coshattee towns and united with the Cumberland war trail in Marshall county. This was the trail used by the Coshattee war parties.

A trail led from Will's Town, a Cherokee town, and united with the Cumberland war trail at the Creek crossing.

A trail led from the Creek crossing on the Tennessee to Niekajack, thence the trail continued to Tellico Blockhouse. That part of the trail from the Creek crossing to Larkins Landing in Jackson county was afterwards a public road and was the first mail route established in Marshall county.

The Great Charleston-Chickasaw Trail crossed Savannah River at Augusta, whence the trail ran to Okfuskee in the upper Creek country. From this town it ran to Coosa, thence to Squaw shoals on the Black Warrior, thence to the old Chickasaw crossing at Cotton Gin. It was first traveled by Col. Welsh in 1698, and afterwards used by the English traders. At the crossing on the Chattahoochie a branch of the trail ran to the Alibamo towns.

WHITE SETTLEMENT; PIONEER ROAD BEGINNINGS; AND EARLY TERRITORIAL AND STATE ROAD EXTENSION.

The foregoing presents in brief, but in as accurate and complete form as in short compass can now be done, the highways of the Southern Indian country about 1775. It was with conditions of land travel and transportation as here indicated that the Colonial and Provincial trade had been carried on about one hundred years, and with these and slowly changing conditions that the settlement of this vast area was to go on for the next quarter of a century.

At the outbreak of the American Revolution in 1776 there was not a white settlement within the limits of the present States of Alabama and Mississippi, and in West Florida, save at Mobile, Natchez and Pensacola. Here and there, however, throughout this vast territory were occasional white settlers, usually traders or trappers, but their stay in any one locality was never permanent. During the progress of hostilities between the colonies and Great Britain, and immediately following its close, from time to time, small portions of refugees from Georgia, and the Carolinas, drifted into what was vaguely known as the Georgia Western Country, and located themselves in the Alabama-Tombigbee basin. Their actual settlements were in the present Clarke, Baldwin and Washington counties. In Pickett's Alabama is an interesting picture of these first settlements.

The close of the Revolution found the number increasing, and the Spaniards encouraged further immigration. The Choctaw Indians had in 1765 ceded a tract of land West of the Mobile River and extending North to the Sintabogue in the present Washington county. Grants of lands in this cession were made, and later, cessions were made indiscriminately in the delta country, now in the vicinity of Mt. Vernon and twenty miles north and several miles east and west.

By 1798 when the Mississippi Territory was formed, these settlements had expanded until there were several hundred souls in the Tombigbee country. The social, economic and political affairs of these people demanded regulation, and on June 4, 1800, Washington county was laid out by executive proclamation. It embraced practically all of the present South Alabama, north of line 31 degrees.

Contemporaneously with the growth of these settlements in the heart of the present Alabama, was the general growth of what is historically known as the Old South-West, perhaps the most remarkable and facinating period in the annals of American settlement. From the Atlantic seaboard the pressure of population westward found its way into the Northwest, the present states of Kentucky and Tennessee, and down the Mississippi River to the Natchez country.

The migration into the Alabama section of the Mississippi territory moved rapidly until checked by the Creek War of 1813-14. Up to that time five counties had been formed. The short, sharp and swift series of campaigns under Jackson, Coffee, Floyd, and Claiborne ending with the battle of the Horse Shoe Bend March 27, 1814, broke the Creek power, and within the next five years more than one hundred thousand people had located in Alabama. The Alabama Territory had been formed March 3, 1817, and Dec. 14, 1819, a joint resolution was adopted admitting the State into the Federal Union.

The coming of the pioneers, their settlement in groups here and there throughout those parts of the State then open to immigrants, and the formation of towns, all affected directly the location and opening up of permanent roads, but at the same time the early Indian trails and the government roads had themselves in a measure shaped and directed the trend of settlement.

The evolution therefore of the pioneer road from the old Indian trails, paths and trade routes was not only an easy, but a natural process. The coming of the white settlers was along these highways, if they could be so dignified Some came, however, by the river routes. Another very natural condition was the planting of little settlements along or near the trails. At first there were no vehicles, but with the larger movements of immigrants and the coming of the wealthier class, the rolling hogshead, the gig and the wagon were employed. The widening of the trails, the selection of new routes, the erection of ferries, the laying of causeways and the opening of houses of entertainment followed.

Twenty-two counties were in existence when the Constitution was adopted in 1819. The Legislatures of 1819, 1820 and 1821 created ten more. These represented more or less contiguous groups of settlements, while at the same time their boundaries were in part determined by physical conditions. County seats were located largely from reasons of convenience to the people, both as regards streams and roads. The latter therefore both determined and were determined by town locations.

Some of these highways will now be described.

NATCHEZ TRACE.

The oldest of these is what is known in Southern history as the Natchez Trace, or the Great Columbian Highway. Its Northern terminus was Nashville, Tennessee; its Southern, Natchez, Mississippi Territory. It was not only the earliest of the highways projected by the Federal government in anticipation of and as a part of its policy of opening up the lower Mississippi and the Old Southwest, but it is to be compared with the old Federal Road only in historic importance. Its route was southwest, passing the present towns of Franklin and Columbia, Tenn., and crossing the Tennessee River a few miles below Mussel Shoals at Colbert's Ferry. The authorization of the road is to be found in treaties with the Chickasaws and Choctaws dated October 21, 1801, and Dec. 17, 1801, respectively. This road constituted the first post route in the Southern country. It entered Alabama in the northern part of Lauderdale county, crossed the Tennessee River at Colbert's Ferry, and passed through the northwest section of the present Colbert (formerly Franklin) county.

OLD FEDERAL ROAD.

The second of the highways in the Gulf country to receive Federal recognition was what is historically known as the Old Federal Road. Originally an Indian trail, by treaty with the Creeks, Nov. 14, 1805, it was formally recognized as "a horse-path through the Creek county, from the Ocmulgee to the Mobile." By 1811 it had expanded to the other with emigrants from the western part of the territory.

It was the great highway from the South Atlantic seaboard and the interior of Georgia to the whole of South Alabama and South Mississippi. Its influence was .far-reaching. In historic importance it is rivalled only by the Natchez Trace. For Alabama history proper it must take first rank. It survives and is in part still used. It entered the State at or near Fort Mitchell in Russell county, and passed in part through the present counties of Russell, Macon, Montgomery, Lowndes and Butler, formed a part of the boundary line between Monroe and Conecuh counties, and continued through Baldwin and Washington counties. Along its route in early days were located Fort Mitchell, Russell county, Fort Bainbridge and Fort Hull, Macon county, Mt. Meigs, Montgomery county, Fort Dale, Butler county, and Fort Montgomery in Baldwin county. Over it traveled Lorenzo Dow and wife, Peggy Dow, Vice-President Aaron Burr, Gen. LaFayette and other celebrities. About 1807, it was extended westwardly from Old St. Stephens to Natchez.

GEN. JACKSON'S OLD MILITARY ROAD.

The Tennessee terminus of this road was the town of Columbia, where it united with or branched from the Natchez Trace. It ran southwest and a few miles east of the Natchez Trace, entering Alabama in the northern part of Lauderdale county and crossing the Tennessee River at Florence. It continued southwest through Tuscumbia, Colbert (formerly Franklin) county, Russellville, Franklin county (where it crossed the Gaines Road or Trace), old Pikeville, Marion county, Sulligent (old Moscow), Lamar (then Marion) county, to Columbus, Miss.

The date and circumstances of its projection and opening are obscure. It had evidently been opened up, in part at least, prior to April 27, 1816, on which date Congress made an appropriation "for the purpose of repairing and keeping in repair the road between Columbia, on Duck River, in the State of Tennessee, and Madisonville, in the State of Louisiana, by the Choctaw agency." Government work under this authorization and subsequent orders of the War Department began in June 1817. The work was completed in January, 1820.

GAINES' ROAD, OR TRACE.

This road extended from Melton's Bluff, at the head of Elk River shoals, on the South band of the Tennessee River, in Lawrence county, to Cotton Gin Fort, on the Tombigbee River. It passed through Courtland, Lawrence county, near LaGrange, Colbert (then Franklin) county, and Russellville, Franklin county, where it crossed Gen. Jackson's Old Military Road. Under the treaty with the Chickasaws of Sept. 26, 1816, it became the eastern boundary of that tribe. It was originally a horsepath used for bringing merchandise from the Tennessee River to the Tombigbee River, whence it was carried by boats to the Indian trading house at St. Stephens.

PENSACOLA AND FORT MITCHELL ROAD.

In the months of June, July and August, 1824, a road, 233 miles in length was constructed from Pensacola, Fla., to Fort Mitchell, Ala. It extended northeast through Covington, Pike, Barbour and Russell counties, probably passing old Montezuma, and Troy. The work of opening up this road seems to have been done under the direction of Capt. D. E. Burch, an Assistant Quartermaster, U. S. Army.

OTHER ROADS.

The necessary multiplication of new roads and the absence of trustworthy early maps makes unsatisfactory any attempt at even a partial list. From the great crossing places on the Tennessee, the Chattahoochee, the Alabama and the Tombigbee Rivers radiated many roads, extending into every section of the State. Tuscumbia, Elyton, Tuscaloosa, Montgomery, old Montezuma (Covington county), Greensboro, Russellville, Demopolis, and other points were important road centres. And long before the removal of the Creek Indians, thoroughfares penetrated every section of East Alabama.

CHARACTER AND DISTRIBUTION OF ALABAMA ROAD BUILDING MATERIALS.

By William F. Prouty,
Chief Assistant Alabama Geological Survey.

We in the South, are just beginning to realize the possibilities and benefits to be derived from a good system of public roads. There are two great essential problems which confront us at the beginning. One problem is, what shall be our method of building and maintaining these roads? The other problem is what kind of materials shall we employ for the different kinds of road in the different parts of the State? We are concerned at this time with the latter question. This question is largely answered by nature in accordance with her distribution of the several materials. As a rule we cannot afford to haul for any great distance road building materials unless they are of exceptional value. We should consequently study the materials immediately at hand for the best results obtainable through them.

In the discussion of the road building materials we shall consider at this time only the natural materials and not the manufactured products. We shall moreover be able only to deal with this class of material in a general way. It is to be hoped that later the results of careful and detailed study of the various materials from characteristic localities throughout the State may be published; the location of possible road building material quarries mapped, and the detailed distribution and character of the better grades of road "metals" more definitely recorded. It is to be hoped that this study may be taken up by counties and the results placed on large-scale maps of approximately an inch to the mile. This detailed study, however, i for the future and cannot concern us at the present time.

The natural road building materials may be classed und three general heads according to their general mode of form tion: First, the igneous rocks, or those which have cool from molten lavas. These may be light colored and with a large amount of the mineral quartz, therefore acid in their nature; or they may be dark colored with a high percentage of ferromagnesian minerals and basic in their character. The igneous rock may, further, be coarsely crystalline, (coarse grained) or finely crystalline (fine grained). Second, the sedimentary rocks, such as have been deposited mainly in water, and show planes of bedding or stratification. These may be either consolidated or unconsolidated. Third, the matamorphic rocks or such as have been subjected to great heat and pressure, and thereby have taken on a structure or texture different from the original one. The rock which is changed may have been originally either an igneous or a sedimentary rock.

Alabama is divided into three distinct physiographic regions (see map, frontispiece) and these three divisions are each marked by a distinct group of rocks. In fact the character of each region is a reflection of the character of rock which underlies it.

The Crystalline Area occupies some 5,000 square miles in the east-central part of the State, covering Lee, Coosa, Tallapoosa, Clay, Randolph, a large part of Elmore and Cleburne, and a portion of Chilton, Talladega and Calhoun counties. This area contains practically all the igneous and metamorphic rocks of the State, the most conspicuous being granites, syenites, "traps," gneisses, and schists.

The Paleozoic Area is marked by the district of the Appalachian valleys and ridges and the Cumberland Plateau. It lies in the north and northeastern part of the State, north and west of the Crystalline belt, and covers about one-fourth the area of the State. This area is characterized by the consolidated type of the sedimentary rocks such as limestones, sandstones, cherts, shales, etc.

The Coastal Plain Area in the southern and western portions occupies a little over one-half the area of the State and is characterized for the most part by unconsolidated sedimentary rocks such as soft limestones, clays and sands.

The chief tests which are applied to the solid rock types to determine their fitness for road material are: hardness, toughness, percentage of wear, and cementing value (see table of tests at end of chapter). The harder and tougher, the less the wear, and the higher the value of cementation, the greater is the value of the rock for roadbuilding. It must be borne in mind, however, that rocks which are very high in resistance to wear are only suited for heavy traffic, while those with rather low resistance to wear which have high cementing value, may be very excellent for use on country roads, where there is lighter traffic. It is therefore evident that one cannot say that this or that material is the best road building material in the State without at the same time designating for what kind of a road.

In the choice of our road building material too much care cannot be taken, for often it is just as expensive to use a poor grade as a good grade material. The resistance to wear, the hardness, the toughness and the cementing value will often need to be determined by a laboratory test, unless the person in charge is familiar with the qualities of the materials used.* The choice of materials extends, for example, even to the character of the clays used. A clay to give the best results in a sand-clay mixture should be high in plasticity and should have a low shrinkage on drying. In addition, the more readily a clay slacks, the more perfect a mixture it will make with the sand and consequently the better the result.

For a matter of convenience let us consider the road building materials of this State as they occur in the three physiographic regions already outlined.

THE CRYSTALLINE AREA.

This area, as has already been said, contains practically every kind of igneous and metamorphic rock. We will consider at this time, however, only those most important in road building, the "traps," granites, gneisses and schists. The gneisses and schists cover the greater part of the area. The gneisses toward the west are granitoid in their nature, but become more and more basic and dark colored as do also the schists, toward the east. The granites occur in large masses, more especially in the western part of the area where there are large outcropping masses known as "flat rocks." Long narrow outcropping dykes and sheets of basic rock, "traps," running in a general northeast-southwest direction, are very numerous throughout the greater part of the crystalline area. Especially is this true in the region of the gneisses and toward the central and eastern part of the area where the whole rock series seems to grow more basic in its nature. The narrow bodies of "trap" sometimes extend for miles in their N. E.-S. W. direction; and in some localities they are very numerous, being several to the mile. The Southern, the Atlantic, Birmingham & Atlantic, and the Central of Georgia railroads all cut through this productive area, and there are many places where the rocks could be worked in the railroad cuts for road surfacing. The "traps" of this area yield one of the most excellent materials for heavy traffic macadam, as they are low in wear and high in hardness, toughness and cementing value. The granites and gneisses and schists follow in about the order named in importance as road metals. All the above named rocks of the crystalline area are more suited for medium to heavy traffic than for light, and find their best use on town and suburban roads rather than on the country roads.

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*The materials to be tested may be sent either to the Office of Public roads Washington, D. C., freight or express prepaid, where they will be tested free; or they may be sent to the State testing laboratory, University, Ala., where they will be tested for a nominal sum, an amount sufficient to cover the actual expenses of such tests.

Up to the present time but little use has been made of the crystalline rocks for road building in Alabama, but there seems to be no reason why, with the growing demand for better roads, quarries should not be opened up along the railroads where high grade material could be placed on the cars at small cost.

In the crystalline area besides the solid rocks already mentioned, residual sands and clays, suitable for the construction of good country roads are to be found widely distributed.

Moreover in the southern part near the Coastal Plain area the Lafayette gravelly loam, which is so much used in other parts of the State for the construction of most excellent roads, is found in considerably extensive patches on the higher lands.

PALEOZOIC AREA.

In the division of the Paleozoic rocks we find a number of road building stones which are of excellent quality. The materials in this area which serve best for road making are, 1st, cherts of the Ft. Payne and Knox formations; 2nd, limestones which are of three varieties: the Cambro-Silurian (Knox), the Ordovician and the Sub-Carboniferous, which is represented by the Ft. Payne and Mountain limestone; 3rd, the sandy shales of the Carboniferous and Sub-Carboniferous; 4th, the residual sands, clay and gravels.

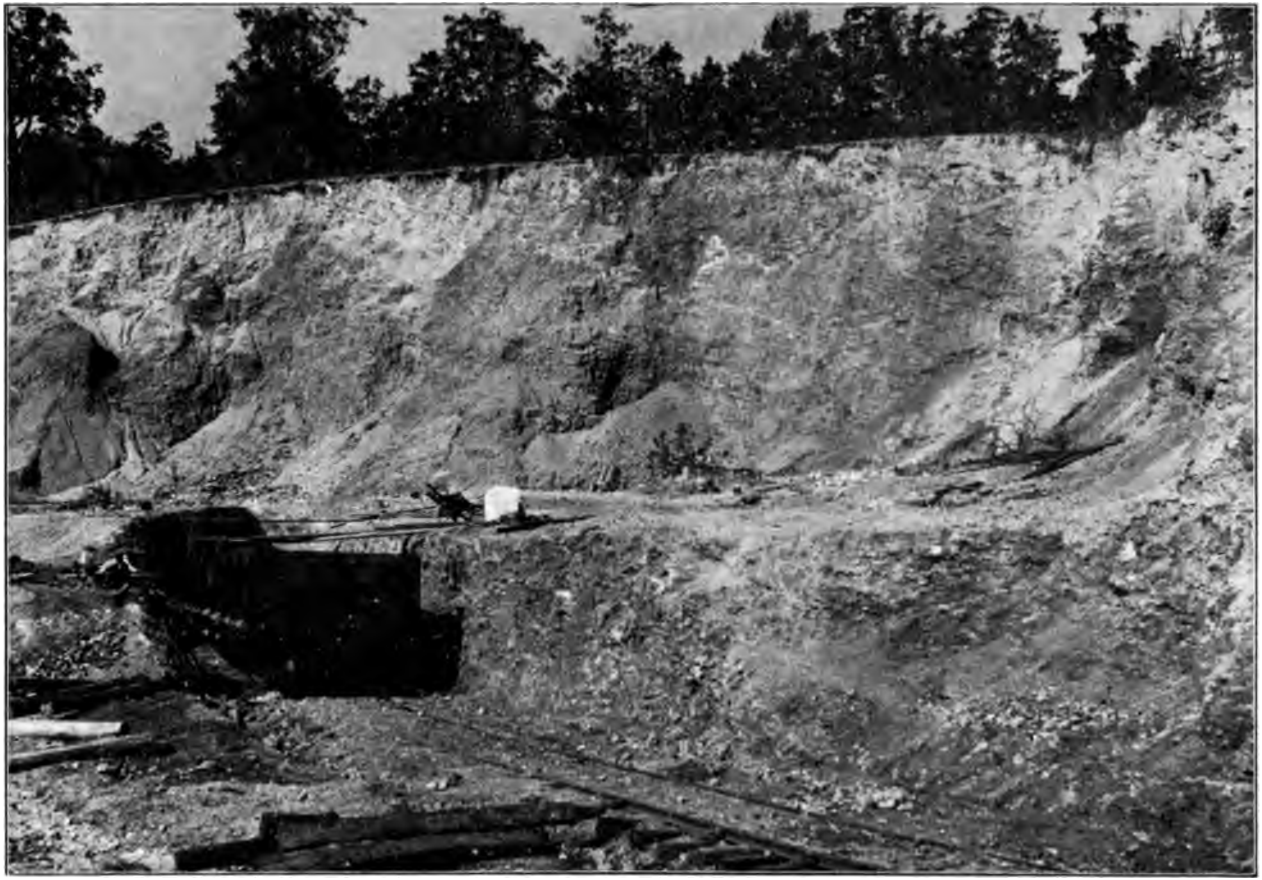
Of these materials the cherts have received, and justly so, the widest recognition. Of the two cherts, the Ft. Payne variety has been the most extensively used and gives, as a rule, better results than the Knox variety, though both are most excellent road metals. The Ft. Payne chert occurs in thick masses and beds in a fragmental condition ready for the steam shovel, while, as a rule, the Knox cherts do not occur in such extensive and pure masses and require more crushing. The cherts from this State show in the laboratory a medium resistance to wear, a good hardness, low toughness, and fair to good cementing value. The comparitively high cementing value of cherts over most forms of quartz is probably due to the fact that it is amorphous rather than crystalline, and is more readily dissolved by ground waters. Cherts are eminently suited for suburban roads of medium heavy traffic.

The limestones of the Appalachian valleys useful as road metals, are closely associated with the cherts and occur in unlimited quantities in places very easy of access. The Ordovician limestone, and the Sub-Carboniferous limestone, are being very much used for macadamizing purposes.

Wherever in the Paleozoic area of the State the cherts and the accompanying limestones occur, there we find a large pop-

A. Quarry in Mountain Limestone (sub-carboniferous) five miles west of Decatur. Morgan County.

B. Quarry in Mountain Limestone (sub-carboniferous) three miles east of Falkville, Morgan County.



Gravel pit in Fort Payne chert near Bessemer, Jefferson County.

ulation of thrifty people drawn to these localities by the rich limestone soils and the mineral deposits. Thus we have in these regions the greatest population in close proximity to high class road building materials.

In all the valley regions of the Paleozoic area we have what might reasonably be called inexhaustible supplies of chert and limestone, and furthermore since these valleys are the great natural passageways of the railroads and since there are hundreds of ideal locations for quarries along the railroads, the cost of delivering these macadamizing materials can be reduced to a minimum.

The great Tennessee Valley which stretches with its broad expanse east and west across the State north of the coal fields, is made almost entirely in limestone or cherty limestone, and the hills to the north are storehouses of chert. The Sequatchee, Wills, Murphrees, Cahaba and Birmingham valleys, are all narrow limestone valleys with either one or both sides paralleled by Ft. Payne chert ridges. The great Coosa valley which is made almost entirely in limestone, is interspersed in many places by ridges of chert of both the Ft. Payne and Knox formations. We see then that everywhere in the valley regions of the Paleozoic area the limestones and chert which are employed either together or separately in the construction of high class macadam roads, are very abundant and easy of access. (See Plate II, A and B, and Plate III.)

In the Plateau regions of the Paleozoic area, the district which is covered mainly by the coal fields, we find a much poorer grade of road building material. Here the ferruginous sandy shales are the best materials obtainable outside of the residual sands and clays which are very common and which, when properly mixed, afford an excellent and cheap country road. Along the northern border of the Plateau region, on the southern edge of the Tennessee valley, bituminous sandstones outcrop which may later be found of great value as a surfacing material in the construction of bituminous roads.

COASTAL PLAIN AREA.

This division covers more than one-half the area of the State, but its road building materials have received far less study than the two areas before mentioned. The possibilities of making good and cheap roads through nearly the whole of this region are most excellent, and as soon as a systematic study of the materials is made and the people properly aroused to the benefits of good roads, there is no reason to suppose that this portion of the State will not have as good highways as any other.

If with the existing geological data one could combine the results of a large number of tests of the materials from representative points in the different formations covering the area, information of great importance for the construction of roads could be readily compiled. From the existing geological data one can draw at this time the most helpful generalizations. There are a large number of formations crossing this portion of the State in belts running in a general east and west direction but swinging in a more northerly direction toward the western border. Briefly stated there are seven such belts which are of interest to us. Four of these belts are characterized by siliceous materials as sands, clays, or sandstones, and three belts characterized by calcareous or limy materials either of a soft or indurated nature. In detail these belts are as follows, beginning on the northern border of the Coastal Plain. (See map, Plate I, Frontispiece) :

1. Alternating sands and clays, a belt some 40 miles wide in the northwest portion of the State and some 10 to 15 miles in Russell county on the east. Throughout the greater part of this belt excellent sand-clay roads could be made with short haul of materials.

2. A belt of "rotten limestone" (Selma Chalk) some 25 miles wide to the west and wedging out in Bullock county. This limestone belt passes through Epes, Demopolis, Selma, Montgomery, and north of Union Springs, and yields the typical "Black Belt" roads which are excellent in dry weather but almost impassable during the rainy season. This limestone

has a high cementing value and would make most excellent roads the year round if sand, gravel or crushed stone were applied to it in the right proportion.

3. A second sand and clay belt increasing from five miles in the west to thirty-five miles in width in the eastern part of the State. These sands and clays are more calcareous in their nature than those of belt 1, and sand-clay roads constructed from these materials should have a high binding character.

4. A second belt of limestone which has an outcrop in the west of about two miles in width and in the east of about ten miles. The limestone making this belt is commonly known as the Clayton or Midway, and varies considerably in thickness of bed and hardness in different parts of its outcrop. Specimens from Wilcox county and elsewhere taken from the more indurated portion show low percentage of wear, good hardness and cementing value, but rather low toughness. The above tests indicate that the limestone would locally make a good macadamizing substance for light traffic. Where not so indurated the limestone shows good cementing values and would be very useful with a siliceous matrix for road surfacing.

5. Overlying the Clayton limestone and outcropping in a belt some 35 miles wide immediately south of it, is a belt of siliceous material made up for the most part of sands and clays of the common type, interspersed by glauconitic (green sand) and shell marls and buhrstones. In this area a judicious mixture of the sands and the marls, or sand and clays should furnish excellent and cheap roads.

6. A third limestone belt, having an outcrop of about 15 miles in width running mainly through Choctaw, Washington, Clarke, Monroe, Conecuh, Escambia, Covington, Geneva and Houston counties. The limestone forming this belt is some 200 feet in thickness and is called the St. Stephens limestone from its typical exposure at Old St. Stephens Bluff on the Tombigbee River. This limestone in the west is rather soft but towards the east becomes indurated and silicified to such an extent that it is locally used for millstones, and would, in this portion of the State, serve as a good surfacing metal for

light traffic roads. The soft limestone of the west portion of the belt has a good cementing value and would be most excellent to mix with the siliceous materials of the belt either to the north or to the south.

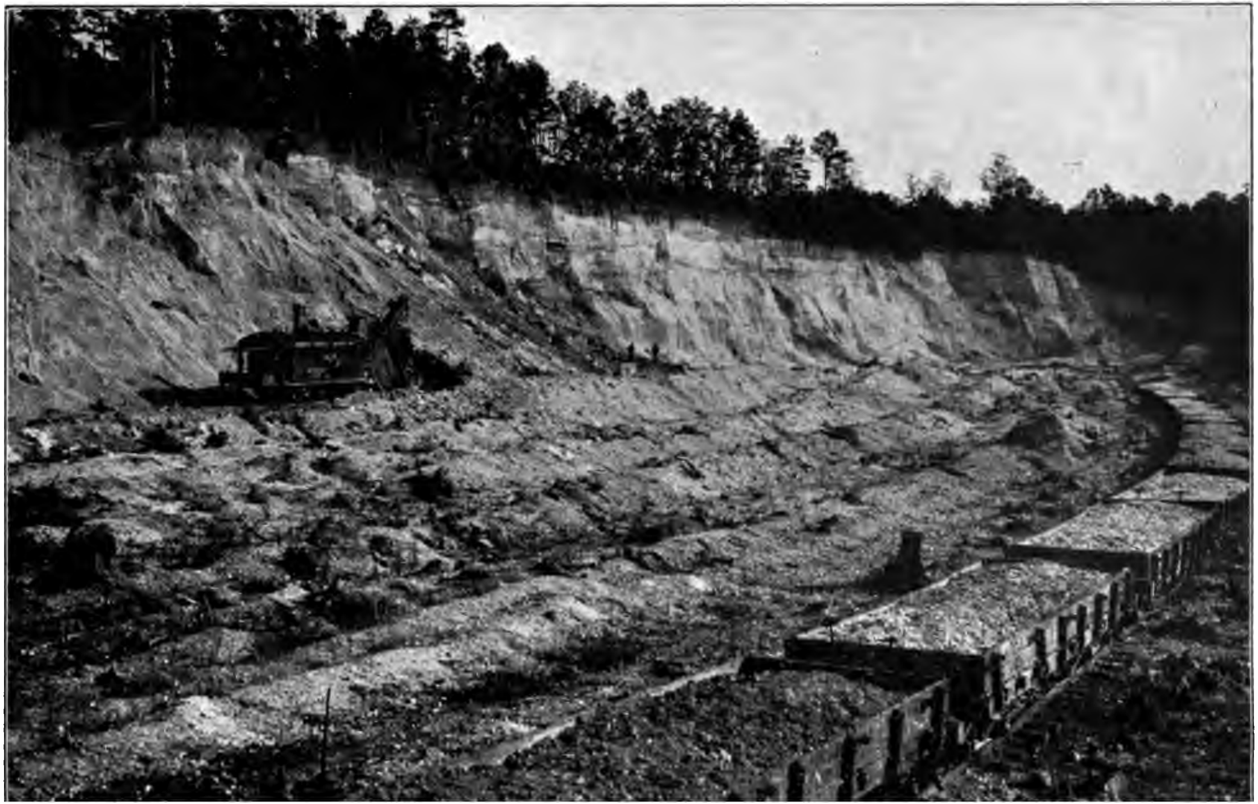
7. Extending from the St. Stephens limestone belt to the Gulf are alternating sands and clays of more recent formation.

In enumerating the road building materials of the different areas and belts I have purposely withheld mentioning until now the most wide-spread and accessible, and at the same time one of the best of the road surfacing materials. This material is known scientifically as the Lafayette formation. It is composed usually of rounded quartzite or chert pebbles and a ferruginous clay. This gravel with its red clay mixture is very wide-spread in its distribution. Not only does it cover from 10 to 25 per cent. of the whole Coastal Plain but it is also found in the other two physiographic areas, especially in the portion bordering the Coastal Plain. These gravels are also found in many of the Appalachian valleys of the Paleozoic area, even toward the northern part of the State.

Lafayette gravel deposits vary in thickness from 0 to 50 feet or more and are found covering as a blanket practically every formation in the State. It is very probable that this formation at one time was more uniformly spread over the surface of the State and especially the southern portion than at present, but stream erosion has removed a large part of it.

The cementing value of this gravel is excellent and when used with the proper percentage of red clay which usually accompanies the gravel, it makes a splendid hard and smooth road for light to medium traffic. Many of the very best suburban roads of the State are made from the Lafayette gravel and clay.

For the larger part of the Coastal Plain area and for a ten or fifteen mile strip bordering the Coastal Plain in the Crystalline and Paleozoic areas, together with many places in the Appalachian valleys, a haul of more than 2 or 3 miles would seldom be necessary for the construction of roads made from



these gravels. Although it is often more economical to open a large deposit near railroad and ship short distance by rail rather than make any long hauls by team. (See Plates IV and V.)

SUMMARY.

To summarize the above briefly, we can say that the State has three general districts which contain materials for the construction of roads differing widely in their character. In one, the Crystalline area, the hard, igneous and metamorphic rocks occur. Here the chief stones for road making are the "traps," the granites, the syenites, the gneisses and schists. Of these the "trap" rock is the most superior in quality but is somewhat limited in its distribution. The granites are confined more to the western portion of the area while the gneisses and schists are very widely distributed. In many places quarries could easily be opened in "traps" and granites along the railroads so that the highest class macadamizing materials which we have in the State for the construction of roads with heavy traffic, could be cheaply and readily shipped to such points in the State as material of this nature might be desired. Throughout the area, also, residual sands and clays and locally gravels occur adapted for the construction of the less expensive roads.

In another, the Paleozoic area, the road materials are still characterized by the consolidated type. They are, however, as a rule, more adapted to medium and light traffic rather than to heavy traffic roads, as is the case with the Crystalline area. Here the chief road building stones are the cherts and limestones and gravels in the valley regions, and sandy shales and residual sands and clays in the plateau regions. Through the richest portion of this area, where there is the greatest call for first class roads, the cherts and limestones are ever present in inexhaustible quantities and easy of access.

In the Coastal Plain area the road building materials are almost entirely of the unconsolidated type, but the distribution of the materials useful for making good roads suitable for light traffic, is very general. The Lafayette gravels which occur in patches over the whole area are perhaps the most useful, and oftentimes the most economically applied, while the ever present sands and clays furnish most excellent materials for a good and cheap road.

In counties lying near the gulf, calcium carbonate in the form of shells of oysters and clams has been very successfully used in the construction of good roads.

There are a number of waste products in the smelting of ores and in the manufacture of different materials which have been successfully used in road building. Most of these products are so limited in quantity as to preclude their discussion at this time. Slag, which is the by-product from the blast furnace, although not of natural occurrence, is produced in such great quantities in our state as to warrant our attention here. This material is being used extensively as a foundation in the construction of macadam roads. On account of its porosity it has good binding qualities making it very suitable for this purpose with a surfacing either of "metal" or bitumen. Its brittleness precludes its use as a surfacing material. (See plate VI.)

While Alabama has not great "trap" talus cliffs like those of the palisades of the Hudson, or the Holyoke range of Massachusetts to draw from, yet all things considered, she is as well, if not more fortunately equipped, than any State in the Union for the construction of good roads throughout her entire area.

[illegible] and in construction of Macadam roads.

No. of samples.	Name.	Specific gravity.			Weight—lbs. per cubic foot			Water absorbed—pounds per cubic foot		Per cent of wear.		French coefficient. of wear.		Hardness.		Toughness.		Cementing value.	
		Max.	*Min.*	*Av.*	*Max*	*Min.*	*Av.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max*	*Min.*	*Max.*	*Min.*	*Max*	*Min.*
15	Amphibolite	3.10	2.70	3.00	193	168	187	1.65	0.04	10.3	1.0	41.7	3.9	19.0	13.5	29	7	235	11
23	Andesite	2.95	2.20	2.60	184	137	162	6.59	0.11	8.1	1.5	26.0	4.9	18.8	7.9	44	7	500+	19
62	Basalt	3.00	2.40	2.80	187	150	175	6.32	0.04	14.7	1.3	30.4	2.7	19.2	5.9	39	6	500+	4
36	Chert	2.95	2.00	2.60	184	125	162	11.10	0.43	27.9	2.7	14.6	1.4	19.7	12.7	26	5	106	4
4	Conglomerate	2.60	2.50	2.55	162	156	159	3.71	2.50	12.7	3.5	11.6	3.2	9.3	9.3	----	----	500+	------
142	Diabase	3.20	2.60	2.95	200	162	184	2.73	0.03	6.3	1.1	36.4	6.4	19.2	12.8	54	4	500+	2
36	Diorite	3.35	2.70	2.95	209	168	184	1.03	0.06	5.7	1.6	25.0	7.0	18.7	16.6	34	8	148	9
105	Dolomite	2.90	2.45	2.75	181	153	172	6.91	0.07	18.6	2.1	19.2	2.2	18.3	4.4	27	4	179	9
5	Eclogite	3.65	2.95	3.25	228	184	203	0.28	0.10	2.9	1.8	22.7	13.8	18.7	17.4	31	14	130	15
6	Epidosite	3.30	2.70	3.00	206	168	187	1.10	0.22	7.4	2.0	19.6	5.4	19.3	10.7	23	10	83	14
11	Felsite	2.80	2.50	2.65	175	156	165	3.13	0.02	3.4	1.9	21.3	11.8	----	----	----	----	------	------
89	Field stone	----	----	----	----	----	----	----	----	10.3	2.1	19.0	3.8	----	----	----	----	------	------
24	Gabbro	3.65	2.80	3.00	228	175	187	0.97	0.04	5.9	1.3	30.8	6.8	18.8	17.0	22	10	115	6
77	Gneiss	3.20	2.60	2.70	200	162	168	1.24	0.08	11.3	1.7	23.0	3.5	19.0	9.0	20	2	110	1
122	Granite	3.00	2.00	2.60	187	125	162	2.77	0.04	24.6	1.1	37.0	1.6	19.2	13.6	31	2	255	3
85	Gravel	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	500+	3
480	Limestone	3.15	2.00	2.70	196	125	168	13.22	0.03	34.2	1.8	21.7	1.2	19.1	0.0	25	2	500+	10
13	Marble	2.85	2.70	2.75	178	168	172	1.04	0.16	14.0	3.8	10.5	2.8	15.9	7.1	9	3	85	15
9	Marl	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	500+	96
19	Mixed stone	----	----	----	----	----	----	----	----	10.3	2.1	19.1	3.9	----	----	----	----	------	------
3	Peridotite	3.55	3.25	3.40	221	203	212	0.33	0.27	4.3	3.6	11.1	9.3	15.0	15.0	12	12	30	25
66	Quartzite	3.10	2.50	2.70	193	156	168	1.53	0.05	7.6	1.6	24.5	5.3	19.7	16.5	30	5	45	0
27	Rhyolite	2.90	2.05	2.35	181	128	147	6.11	0.03	9.7	1.7	23.0	4.1	19.7	15.3	42	6	500+	10
193	Sandstone	3.25	2.00	2.55	203	125	159	11.60	0.02	41.7	1.0	40.8	1.0	19.5	0.0	60	2	500+	3
87	Schist	3.20	2.65	2.95	200	165	184	1.35	0.06	12.8	1.8	22.6	3.1	18.9	0.9	35	3	232	7
9	Shale	2.70	2.50	2.65	168	156	165	4.84	0.50	16.2	3.2	12.6	2.5	17.7	13.9	12	3	367	28
33	Slag	3.90	2.00	2.80	243	125	175	4.40	0.04	13.5	2.7	14.6	3.0	18.0	10.7	21	3	463	1
42	Slate	3.35	2.60	2.75	209	162	172	2.10	0.05	6.9	1.6	24.4	5.8	19.7	1.1	40	1	500+	1
17	Syenite	3.05	2.15	2.70	190	134	168	4.21	0.10	14.4	1.7	23.5	2.8	19.2	17.3	34	8	375	16

*For explanation of results see following page.

EXPLANATORY TERMS USED IN TABLES OF ROCK TESTS.

RESISTANCE TO WEAR.

Resistance to wear is a special property in rock, and although it depends to a large extent upon both the hardness and the toughness of the rock it is not an absolute function of these qualities.

The per cent. of wear in the table refers to the dust and detritus below one-sixteenth of an inch in size worn off in the abrasion test. The test is made in the following manner: Eleven pounds (5 kg.) of broken rock between 1 1-4 and 2 1-2 inches in size, 50 pieces if possible, are placed in a cast iron cylinder mounted diagonally on a shaft and slowly revolved 10,000 times.

The French coefficient of wear is obtained by dividing 40 by the per cent. of wear. Thus a rock showing 4 per cent. of wear has a French coefficient of wear of 10. The French engineers, who were first to undertake road-material tests, adopted this method of recording results. They found that their best wearing rocks gave a coefficient equal to about 20. The number 20 was therefore adopted as a standard of excellence. In interpreting the results of this test a coefficient of wear below 8 is called low; from 8 to 13, medium; from 14 to 20, high; and above 20 very high. Rocks of very high resistance to wear are only suited for heavy traffic.

HARDNESS.

By hardness is meant the resistance of a rock to the grinding action of an abrasive agent like sand, and is tested as follows:

A core 1 inch in diameter, cut from the solid rock, is faced off and subjected to the grinding action of sand fed upon a revolving steel disk against which the test piece is held with a standard pressure. When the disk has made 1,000 revolutions the loss in weight of the sample is determined. In order to report these results on a definite scale which will be convenient the method has been adopted of subtracting one-third of the resulting loss in weight in grams from 20. Thus a rock losing 6 grams has a hardness of 20—6/3 or 18. Experience has shown this to be the most convenient scale for reporting results. The results of this test are interpreted as follows: Below 14, rocks are called soft; from 14 to 17, medium; above 17, hard.

TOUGHNESS.

By toughness is meant the resistance a rock offers to fracture under impact; such, for instance, as the striking blow given by a shod horse. This property is tested in a specially designed machine built on the pile driver principle, by which a standard weight is dropped upon a specially prepared test piece until it breaks. The height in centimeters of the blow which causes the rupture of the test piece is used to represent the toughness of the specimen. Results of this test are interpreted so that those rocks which run below 13 are called low; from 13 to 19, medium; and above 19, high.

CEMENTING VALUE.

By cementing value is meant the binding power of the road material. Some rock dusts possess the quality of packing to a smooth, impervious mass of considerable tenacity, while others entirely lack this quality. Cementing value should not be confused with the property possessed by Portland cement, which causes it to set into a hard, stone-like mass when mixed with water. The cementation test is made as follows:

The rock sample is ground in an iron ball mill with sufficient water to form a stiff, fine-grained paste. From this paste small briquettes 1 inch (25 mm.) in diameter and 1 inch high are molded under pressure. After thorough drying the briquettes are tested under the impact of a small hammer which strikes a series of standard blows. The number of blows required to destroy the briquette is taken as a measure of the cementing value of the dust. Some rock dusts, when thoroughly dried into compact masses, immediately slake or disintegrate when immersed in water. It is considered that the tendency to act in this way is not a desirable characteristic of a road material, as it would lead to muddy conditions on the road surface after rains. The test is interpreted so that cementing values below 10 are called low; from 10 to 25, fair; from 26 to 75, good, from 76 to 100, very good; and above 100, excellent.

WEIGHT PER CUBIC FOOT.

The weight per cubic foot refers to the weight of the material in the form of a solid and not as broken stone.

‡TABLE SHOWING TESTS OF TWENTY-SEVEN DIFFERENT SAMPLES OF ROCK

Kind of Material.	Geological age or Formation.	Locality.	Specific Gravity.	Weight per cubic foot.	Water absorbed per cubic foot.
1. Limestone	Pelham	Dorville Switch, Jeff'n Co.	2.70	168	.10
2. Limestone	Pelham	Anniston, Calhoun Co.	2.7	168.4	.27
3. Limestone	Selma chalk	Faunsdale, Hale Co.	2.61	162	2.57
4. Limestone	Selma chalk	Uniontown, Perry Co.	----	----	----
5. Limestone	Selma chalk	Faunsdale, Hale Co.	----	----	----
6. Limestone	Selma chalk	Livingston, Sumter Co.	----	----	----
7. Limestone	Sub-Carb.	2 m. from Hartsell, Morgan Co.	2.65	165	.62
8. Limestone	Sub-Carb.	Cullman, Cullman Co.	2.7	168	.55
9. Limestone	Eocene	Snow Hill, Wilcox Co.	2.6	162	2.57
10. Limestone	Eocene	Furman, Wilcox Co.	2.6	162	2.76
11. Chert	Knox?	Leeds, Jefferson Co.	2.6	162.5	.7
12. Decomposed chert	Fort Payne	Anniston, Calhoun Co.	2.6	162	.7
13. Chert	Fort Payne	Francis, P. O., Calh'n Co.	2.45	153	1.74
14. Chert	Fort Payne	Leeds, Jefferson Co.	2.6	162	.64
15. Chert	Fort Payne	Birmingham, Jeff'n Co.	2.45	153	3.40
16. Chert	Fort Payne	Birmingham, Jeff'n Co.	2.55	159	2.24
17. Sandstone	----	Hartselle, Morgan Co.	----	----	----
18. Sandstone	----	Cullman, Cullman Co.	2.45	153	.94
19. Limestone	----	Walthall's, Perry Co.	----	----	----
20. Gravel	Pleistocene	Athens, Limestone Co.	----	----	----
21. Gravel	Lafayette	Tuskegee, Macon Co.	----	----	----
22. Gravel	----	Tuskegee, Macon Co.	----	----	----
23. Cherty Gravel, white	Lafayette?	Tuskegee, Macon Co.	----	----	----
24. Cherty Gravel, yellow	Lafayette?	Tuskegee, Macon Co.	----	----	----
25. Limestone	Nanafalia	Pineapple, Wilcox Co.	2.5	156	4.89
26. Slag	----	Alicefurnace, B'ham	2.7	168	.54
27. Slag	----	Birmingham	2.55	159	1.32

‡For explanation of tests see previous pages.

NT THE OFFICE OF PUBLIC ROADS FROM DIFFERENT PARTS OF ALABAMA.

cient of wear.	Hardness.	Toughness.	Cementing value.	REMARKS.
	17.7	8	Good (57)	Rather hard with average resistance to wear, low toughness and goo cementing value.
	15.2	9	62	Fairly high in hardness and slightly below average for limestone i toughness; high in resistance to wear; good cementing valu Best suited for light traffic troads.
	---	--	20	Best suited for very light traffic roads or to be used as a binding ma terial with other rocks.
	---	--	14	Below average in cementing value.
	---	--	Excellent	Will make an excellent binding material with either rock or sand.
	---	--	Excellent	Will make an excellent binding material with either rock or sand.
	12.9	6	Good	Low in hardness, tougness and resistance to wear. A light traffi road material.
	15.7	8	Good	A satisfactory road material under light traffic.
	17.1	8	Good	Best suited for light traffic roads.
	10.3	7	55	Soft limestone, average wear and good cementing value. Light tra fic road.
	---	--	Low	
	---	--	Fair	Cementing value will increase under wear.
	19.3	11	Fair	Cementing value will increase under wear.
	---	--	Fair	Light traffic roads.
	---	--	Good	Medium resistance to wear.
	---	--	Good	Medium resistance to wear.
	---	--	---------	Nature of material prevents tests.
	15.1	10	Good	Medium hardness, low toughness.
	---	--	37	Will develop fair cementing value if rolled wet.
	---	--	Ex. (267)	
	---	--	Ex. (400)	28% of this gravel was below 1-16".
	---	--	75	Low cementing value caused by large amount of mica plates.
	---	--	15	
	---	--	19	
	11.*	6	65	*New scale. Fairly hard, medium wear good cementing value.
	---	--	Excellent	
	14.2	6	Fair	Medium hardness, low toughness and resistance to wear. Light traffic

MACADAM ROADS IN ALABAMA.

By R. P. Boyd, Assistant State Highway Engineer.

The northern part of Alabama is rich in limestone and this material will necessarily be an important factor in the improvement of roads in that locality. The limestones in this section are of the upper and lower sub-carboniferous rocks of which there are two varieties: The lower limestone, gray, coarse-grained and crystalline; the upper, blue, fine-grained with but few crystals. The latter is the best road material and should be used when practicable. Quarries can generally be located along or near the roads and rarely will the stone have to be hauled over five miles. In locating a quarry, the cedar tree is an almost infallible sign of limestone.

Care should be taken in selecting the quarry site, for the quarrying is an important item in the cost. There are two distinct types of quarries: those where the stone lies in ledges or cliffs above the surrounding surface, in others the stone is found in flat ledges below the surface. I have found the latter, when free from water, were the best and cheapest to quarry, offering the best opportunity for mechanical elevation to the crusher. The cost of quarrying is approximately from forty to sixty cents per cubic yard, depending on the nature of the rock, the amount of stripping necessary, and the amount of mud-seams encountered.

Surveys, profiles and plans should be made in the regular way. Special attention should be given to the location of the road, and where old roads are followed, steep grades should be avoided. A five per cent. grade should be the maximum for it is practically impossible to maintain a water bound macadam road on a steeper grade. The maintenance in a few years will be greater than the cost of re-locating, even if the right-of-way must be purchased.

The limestone section offers excellent and comparatively cheap drainage, for generally ledges of rock can be located that make excellent dry masonry culverts up to spans of four feet. These culverts are durable, cheap and not unsightly. An excellent concrete can be made from the crushed stone and screenings, which makes permanent and ornamental culverts, and when reinforced, can be used for bridges of small spans.

The grade should be finished and allowed to pack or settle for a period of two weeks before any macadam is laid. The sub-grade should be prepared at least one hundred feet in advance of the macadam. All soft places should be dug out and filled with firm dry earth and all holes filled. The sub-grade is then crowned with the road machine to the same crown that the finished road will have and then thoroughly rolled with a ten-ton roller. If any weak places are discovered while rolling, they should be taken out and replaced with suitable material and rolled again. The sub-grade, or foundation, is the most important part of any road and too much care cannot be given to this detail. A good road can never be made or maintained on a poor foundation. Macadam should never be put down in mud or soft earth, as it is absolutely essential that the sub-grade be dry and hard before the rock is spread.

The macadam should be laid in three courses, as follows: The first course of number one stone from 1 3-4 inches to 3 inches in size, spread from 4 to 5 inches thick and rolled with a ten-ton roller until the rock ceases to creep before the roller; the second course of number two stone, from 1-2 inch to 1 3-4 inches in size spread 3 to 4 inches thick and rolled as the first course. The first two courses can be dumped on the roadbed and spread to a better advantage with a small road machine with some assitance by raking. The third course, the binder, of No. 3 stone from dust to 1-2 inch in size, spread just thick enough to fill the void and form the bond. The best results are obtained by dumping the screenings on the side of the road and spreading by hand with shovel and rake. Sweeping with a stiff broom aids in working the binder into the interstices. After the screenings are worked in dry as much as possible, the surface should be flushed with water from a sprinkler and rolled as close behind the sprinkler as possible.

The sprinkling and, rolling should be continued until the macadam is thoroughly bonded and ceases to creep before the roller. In many instances where water is scarce and the haul is long, it is cheaper to wet each wagon load of stone before it is dumped on the road. This can be done at some convenient well, stream or hydrant as the wagons pass by and it serves the purpose as well as sprinkling the material after being laid. The above courses give a thickness of about six and one-half to seven and one-half inches when completed.

The number two stone is the wearing surface and care should be taken not to get the screenings too thick and leave a crust over the number two stones. While it may appear smooth and hard at first, after a freeze or frost, a vehicle will pick it up in patches and cause holes and raveling. In rolling each course, the rolling should commence at the edges and work toward the center, preserving the crown of the road. The edges of the macadam should be kept straight and even by using six-inch boards to hold it in place. After the second course is laid, the boards should be removed and the berm rolled as the macadam is rolled.

The crown or slope to the ditches should be about five-eighths of an inch to one foot and on grades this should be increased enough to cause the water to drain to the ditches instead of down the roadbed. The berms or earth shoulders should never be less than three feet wide on each side of the macadam. These berms may be formed either by plowing out the center for the sub-grade and throwing up the berm with the road machine, or by taking the earth from the back of the ditches with drag scrapes. The latter method is best on fills as the height of the road will be increased. On new roads, especially on grades, the berms are liable to wash in gullies. This can be remedied by sodding with grass and in some cases, as in sandy sections, a thin layer of number one stone laid without rolling, will prevent washing.

The width of macadam roads is best determined by the amount of travel over the roads. Owing to the cost, few counties can build a macadam surface as wide as gravel or chert.

For the ordinary country road, a grade of twenty feet with macadam ten feet wide will answer every purpose. A road of this width will cost approximately three thousand dollars per mile. On heavily traveled roads and near towns the macadam should be wide enough to allow teams to pass without getting off the metaled surface. Macadam is the most costly road material in this State, but in some localities it is the only road material available, and it will, of necessity, have to be used. It makes an excellent road surface and when properly maintained is the most durable road material in this State. (See Plates VII and VIII.)

Splendid roads are made of oyster shells, the construction of which is similar to the construction of macadam roads. After the grade and sub-grade is prepared a course of natural shells is placed the required width to a depth of six inches and rolled, after which a second course of shells, which have been run through a crusher, is placed to a depth of two inches, dampened and rolled until the road is firm and hard.

GRAVEL AND CHERT ROADS.

By J. T. Bullen, C. E.
County Engineer, Montgomery County.

Gravel roads, or so-called gravel roads, vary greatly in the quality and quantity of gravel, and the methods of construction, in different communities.

In some counties, a gravel road means a chert road; in other counties, a gravel road may be only a good quality of sand-clay road, and there are many grades between these two extremes. To be specific, from a geologist's point of view, a gravel road would mean a road surfaced with fragments of rock, worn round under the influence of water or atmospheric conditions: but taken in a broader sense, any fragment of rock, mixed with sand, or unmixed, would properly be called gravel. It is well to bear in mind these different qualities when a question of cost is discussed.

Generally a county cannot afford to go out of its own boundary for road material. The problem then is generally how to best make use of local material; and since my subject is *gravel* roads, I shall confine my statements to roads built of that material.

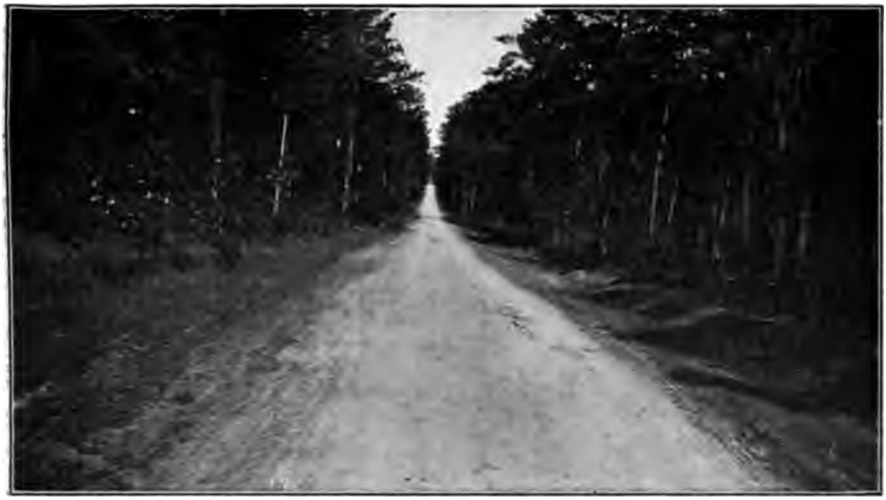
In building a gravel road, the foundation, or sub-grade, is one of the essential parts. If the sub-grade is a porous soil, sandy or loamy, or a sandy clay, and naturally well drained, it will require less gravel to make a good road. The stiffer the clay, the greater the quantity of gravel necessary. Four or five inches on a porous soil will serve as well as eight or nine inches on a prairie mud.

As to Quality.

Chert, when of the best varieties, such as Fort Payne chert, is one of the very best road materials. If it is crushed or broken by hand so that no piece of it is over two inches in diameter, and the majority even less, it will make a very last-

A. Macadam Road, Morgan County looking east from

B. Macadam Road, Morgan County, showing cut



Macadam Road, looking west, three miles east of Hartselle, Morgan County.

ing road. If any fragments of larger dimensions are used, even under the bottom, it will soon wear enough to expose the big lumps, and then you will have a road that is very rough, hard on horses, and especially hard on rubber tires.

Chert binds together better than any of the pebble gravels, or even limestone macadam, and the best chert road has little or no dust, and consequently little or no mud.

However, don't be misled, and believe that to specify chert is sufficient, for there are several kinds of chert found in one county, one very hard and durable, and another soft and chalky. See that you are getting the durable kind.

It is well sometimes to specify that the chert be spread in two layers, in order to prevent large lumps from being covered up.

I have seen a road built of clean chert collected from the foot of steep hills, where it had been washed against trees and fences, and the small quantity of black loam found with it made a fine binder.

I have used a chert that had few particles over one-half inch in diameter, and it made a very excellent road.

Chert is some times found in quarries of almost solid formation and when blasted separates into several sizes from very small particles up to the size of a water bucket. Chert of this sort is separated into uniform sizes by screens and applied on the road in layers similar to standard macadam construction and when so handled makes an almost perfect road.

After the chert gravel comes the water-worn crystalline variety, found sometimes in the bed of streams, mixed with sand or entirely clean, and again found in banks mixed with sand and clay.

The gravel with only sand for a binder will take a very long time to bind into a smooth, hard road, until some loam or clay or other binder is added.

A little ferruginous clay mixed with the gravel will, after it is thoroughly wet, set hard and firm. And even these bank or pit gravels vary greatly both in hardness and toughness, and particularly in the proportions of sand and clay found with them. There seems to be streaks in all pits, sometimes a few feet wide, and sometimes many yards wide; sometimes the streaks have an excess of sand, and then again an excess of clay, rarely or never an excess of rock.

Sometimes the overburden of clay or sand and clay covering the gravel is only a few inches thick, then again it will run from three to ten feet thick. And again, it will generally be observed that the first two or three feet in depth of gravel contains more clay than the next layer lower down, and the pits frequently run into strictly sand gravel at a depth of four to eight feet.

Bank gravel is not to be judged offhand, for you may take a sample of gravel from one pit, and screen it carefully, or wash it, and find fifty per cent. of gravel remaining on the screen, and a sample from another pit, after screening or washing, may show only thirty-five per cent. of rock, and yet be a better gravel for road purposes. In the first sample, the balance of aggregate may be clay, in the second sample, containing actually fifteen per cent. less rock, the balance of aggregate may be a well balanced sand and clay, and under traffic in wet weather would hold up a heavier traffic than the first sample. And like concrete, a graded gravel with fine and medium and coarse rock will make a better, more uniform road than all coarse or all fine gravel. Except for grading as above mentioned, uniformity of the surfacing material is very necessary for the best results. If, in the hurry to load at the pit, one wagon is loaded with material from a clay streak and another from a sandy streak, and a third from a streak especially full of rock, it stands to reason that the road surface will have the same streaks. In dry weather, the clay streak will be smooth and hard, and the sandy streak will be loose; and in wet weather the reverse will be true. And after a considerable period of time, the extra gravelly streak will be hard and higher than the balance of the road, having worn less.

It is well to specify a gravel containing not less than sixty-five per cent. of rock to be retained on a No. 10 riddle, with balance of aggregate about one-third clay and two-thirds sand. The majority of gravel now used in Montgomery county runs nearly 75 per cent. rock and about the above proportions of sand and clay.

The gravel itself is brittle, and breaks easily under traffic, forming a binder of itself.

I find, as a general thing, that the pebble found in sand banks is a harder, more durable gravel than that found mixed with clay. And the hard gravel, when screened and mixed with a good clay, makes a very lasting road; after screening, enough sand remains to keep the clay from being too sticky.

It is much easier to build a road of sand and clay gravel than of limestone, or any other macadam surface. The gravel is easier to spread and shape, binds more readily, and frequently has enough moisture in it to save the expense of sprinkling.

A roller of, say ten tons, or even five tons, will be of service in building gravel roads, but where there is heavy traffic, or much light traffic, a roller is not necessary, as in macadam road construction. However, it is very necessary to keep the gravel surface to a crown, either by rakes, or better, by road machines, until it has packed hard and smooth. The traffic will do the rolling, but the road machine dressing it daily for, say, ten days after traffic is turned on it, will fill the ruts and keep the crown in shape, and after a few rains or daily sprinkling a hard, smooth road will result. Care should be exercised in spreading gravel uniformly over road surface, but it is by no means so important as in macadam roads, for if the road machine is frequently used, a very even distribution of gravel will result.

I sometimes specify that the sub-grade for gravel shall be cut out, leaving a solid shoulder on each side, cutting half the depth of gravel, and using the earth cut out to build up the other half of shoulder, requiring the sub-grade to have the same crown as the finished road, generally three-fourths of an inch to one foot, the gravel to be spread same depth at center and at sides. Then again, I specify grade to be built flat, with the crown formed by the gravel, spreading gravel, say, nine inches deep at center, and six or seven inches at sides, and shoulders to be then given a crown with road machine, and gravel feathered out at edges with road machine. On a wide grade, with light travel, the latter way is perhaps the better; on a narrow grade the former is better.

And when the former method is used, and the sub-grade is not of a porous material, it is well to have lateral trenches across the shoulders, dug to the depth of gravel, and six inches wide, and filled with clean gravel, to allow the water percolating through gravel surface to escape from the subgrade to side ditches. These blind drains are especially serviceable at the foot of grades.

I usually specify that all gravel shall be back-dumped; that is, hauled to far end of work first, using sub-grade to travel over. This travel on sub-grade packs it as few rollers could do,—develops the soft spongy places, and saves the wear of the gravel.

It is not always wise to adhere to this rule, for in some cases the reverse is the better way. If sub-grade is sandy and difficult to haul over, the travel will not pack it, and the rule would only make a contractor bid higher than if allowed to build road and advance over it as fast as completed.

Then, two, if gravel is put down, and hauled over at once by a contractor with heavy loads of gravel, it will more surely be dressed with road machines, and be in a compact finished condition by the time the far end is spread.

Again, on a clay sub-grade, after rains, heavy loads are impossible, and contractors bid to cover delays.

So in this rule, as in most others, common sense must decide which it is better to specify.

I also specify the use of seven-inch or nine-inch planks, as the case may be, to confine the gravel in sub-grade trench, or on flat sub-grade, to insure a uniform depth of gravel, as well as a true alignment, only a few hundred feet of boards being necessary, as they are taken up and carried forward as fast as the berms, or shoulders, are completed.

Pegs at intervals of ten feet down the center are sufficient to insure proper depth.

I believe it a much better plan to specify so many inches of loose gravel than so many inches of compacted gravel. You can see the quantity of loose gravel spread by the boards and pegs, and you can require it rolled until you are satisfied; if it compacts to eight inches, or six inches, there is no dispute with the contractor as to depth of finished work.

You may specify nine inches in depth loose, twelve feet wide, which would require 1,760 cubic yards of gravel. Allow one or two per cent in excess of that amount, to make it practical. Have inspector require the loose gravel to come flush with top of boards; agree to pay the contractor not over two per cent. in excess of the theoretical amount required, and he will be sure to have his sub-grade free of holes.

There are few gravels that contain any appreciable per cent. of clay that will compact alike; sometimes they will compact fifteen per cent. under rolling, and in others will compact as much as thirty per cent. If you plug the finished road, in an endeavor to see if the full nine inches has been applied, you will find the finished depth varies not only with the amount of rolling, but with the proportions of sand and clay and pebbles in the aggregate.

Montgomery county owns a large gravel pit, and pays a contractor 12 1-2 cents per cubic yard to load the gravel on cars, which is done with a steam shovel. The shovel has a capacity sufficient to load about forty cars a day, averaging twenty-five cubic yards to the car. From the pit the gravel is distributed through the county to the railroad stations nearest the work, and hauled from the station to the road by teams.

In one contract, we have allowed the contractor to build a narrow-gauge railroad down the grade for some miles, and the price bid by the contractor to whom the work was awarded was $10.000.00 cheaper than any of the bids made by contractors who figured on doing the work altogether by teams. The contractor uses three-yard cars and a Shay geared locomotive, and is able to pull a heavy load up grades as steep as 5 per cent. I believe this method is a good one for large contractors on long hauls.

As to Cost.

The cost of a road, gravel or macadam, can be likened to the cost of a house. It depends on what kind of a road will meet your requirements. Houses vary from cheap, two-room houses, costing, say, two hundred dollars, to the mansion costing two hundred thousand. And roads will vary in the same way. Some very fair roads cost only a few hundred dollars, and others cost as high as two hundred thousand dollars, or more, per mile.

The amount of grading, the bridging, the width and depth of gravel, and the length of haul, are all important factors in the cost of roads.

A road built over a gently undulating country may have easy grades, with only light grading, and the culverts and bridges may be few in number, and the gravel may be found adjacent to the road, requiring only a short haul.

Again, the grading may be five to ten feet high to get above high water, and bridges frequent and expensive; the gravel may be five or six, or even ten or a hundred miles from the work, and a railroad haul, as well as a long wagon haul, necessary to deliver it.

A good team will make from twenty to thirty miles a day. On short hauls, as many as twelve or fifteen loads of gravel may be delivered on the road by one team; and if teams could be procured for $3.50 per day, the gravel would cost 23 1-3 cents per load for hauling. A road 16 ft. wide and 9 in. deep would require 2,347 cu. yd., which, at 23 1-3 cents, would be $546.85 for hauling. If the gravel was five miles from the work, the same team would probably make three trips per day, making cost of hauling per cubic yard, at same rates, 70 cents per cubic yard, or $1,642.90 for hauling sufficient gravel for one mile of road; in other words, for the same identical result as to road surface, the road built with long haul would cost, in round numbers, $1,100.00 per mile more than the road with short haul. I make this comparison to show how rapidly (under varying conditions) the cost for the same grade of road may vary.

Under average conditions, a road graded 20 feet wide, with gravel 12 feet wide and 8 inches deep, can be well built for

$2,400.00 per mile. Under most favorable conditions, the cost may be as low as $750.00 per mile; hardly less, if it is well built.

MAINTENANCE.

It is easy enough to keep a few miles of gravel road in repair, but when the mileage gets up to the hundreds, it becomes a problem.

The patrol, or continuous repair system, is good, if you can carry it out.

We have tried negroes with mules and carts, but each negro required a good foreman behind him, to get any results. Where reliable white men could be employed for nominal sum to patrol a section of road and keep it up, the patrol system would give good results.

In Montgomery county, we are working under the general State law, and have divided the county into nine road districts, and hired an overseer for each district, at $50.00 per month, to take charge of the roads in his district. Each overseer is given two good wagons and teams, two tents, a road machine, shovel, plows, bush-hooks, etc. Before beginning work, each overseer is required to ride over his district and get the name and address of each person in his district liable for road duty, and a copy of said list was furnished the county engineer. He keeps a regular account with each road hand, charging him with ten days work, or $5.00 a year, and crediting his account from week to week as the overseer reports that he has worked or paid.

Since all overseers are paid a salary, and their job depends on their making the road hands work or pay, it is a much easier matter to get the work done.

This is the first year Montgomery county has tried this system, and it is not perfected, but it is a wonderful improvement over the old methods.

The most intelligent overseers are accomplishing great results, and I believe they will improve rapidly with experience. The outfits under overseers can do little new work, but are supposed to maintain the present roads in the districts.

When a gravel road becomes worn irregularly,—a hole here and there, we use a scarifier of several tons weight, with four spike teeth at each end, to drag over gravel and loosen the surface to a depth of several inches. Then by reshaping the surface with the road machine daily until travel packs it smooth, we have a cheaply repaired road.

If the road surface has deep holes, it is better to refill them with fresh gravel, before scarifying the surface. It is a difficult thing to make a smooth, satisfactory patch, but with the scarifier it is simple.

The scarifier is intended to be dragged by a traction engine, or steam roller, but we frequently hitch twelve mules to it and plow up the road for much less than it could be done with six or eight mules and a rooter plow.

As to Length of Life.

One of the chert roads in Montgomery county held up well under fourteen years of travel, though large lumps were allowed on the road, and they projected from two to six inches above the general surface, making a hard road, but a very bad one on horses and tires.

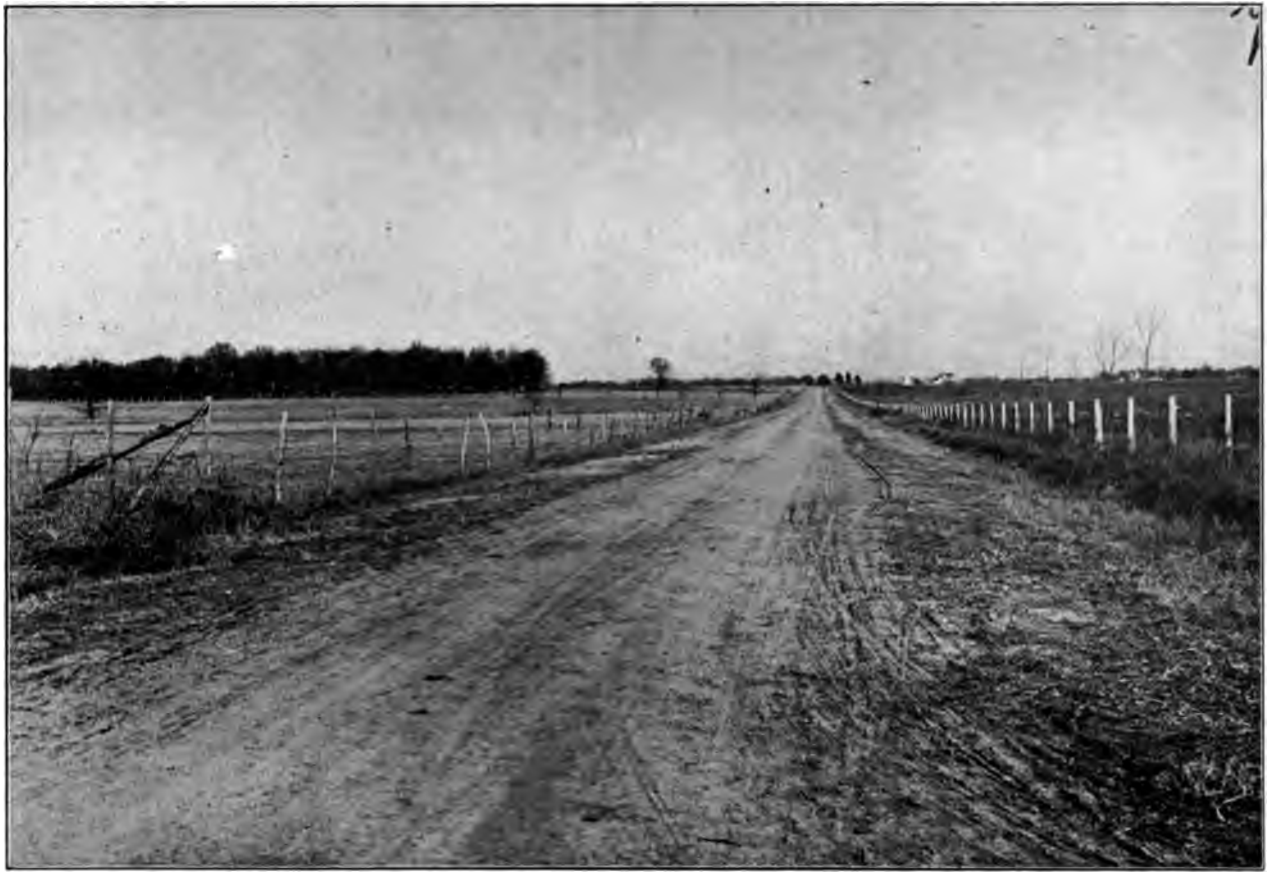
The screened gravel roads (hard, flinty, water-worn pebbles), under heavy travel, held up pretty well for seven or eight years; after eight years they were badly worn and rutted.

The clay gravels unscreened lasted five or six years.

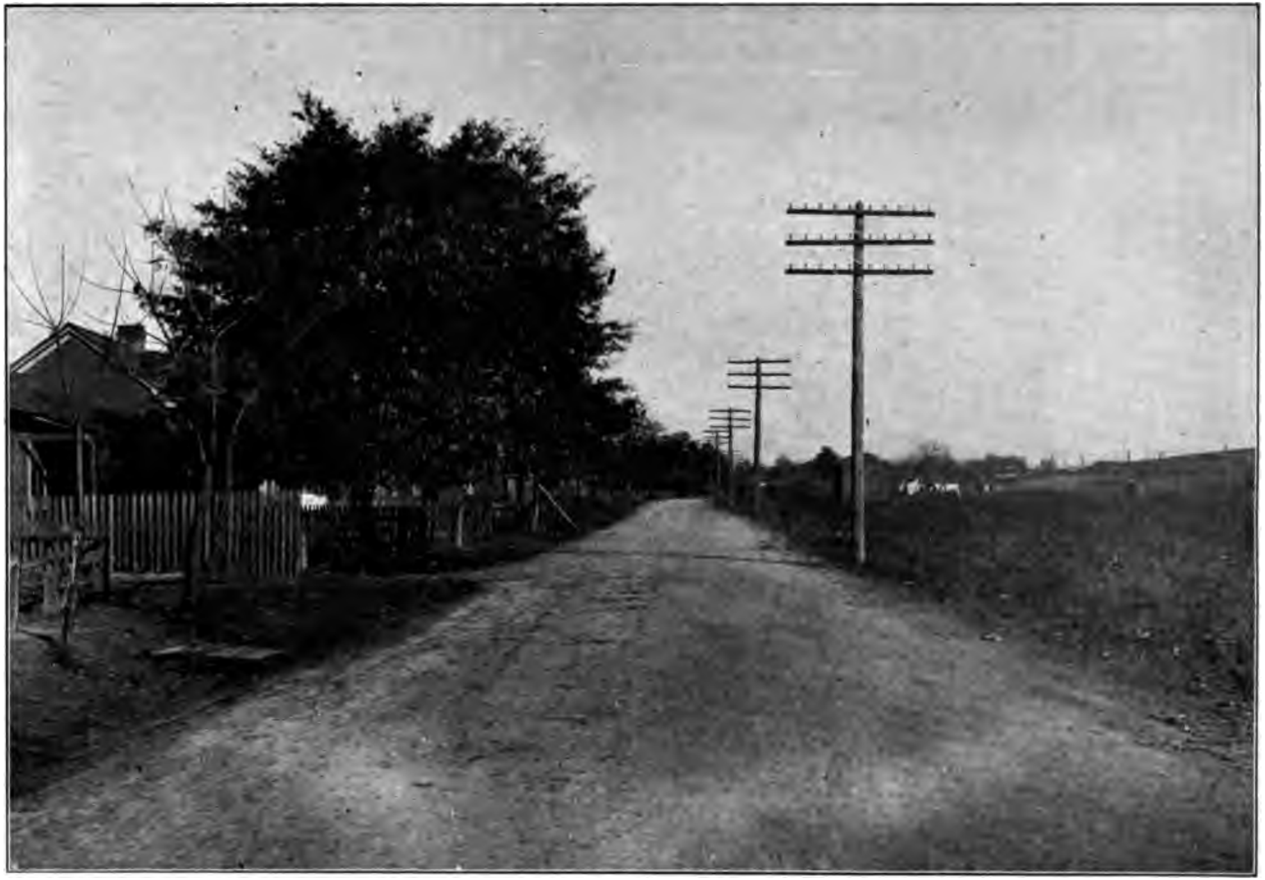
Repairs on a gravel road, like on any other road, should begin almost as soon as completed; and especially so if there are any grades deeper than 3 per cent. It is a mighty good investment to reduce grades to 3 per cent. or less, to save repair bills; for one torrential rain will begin the destruction of the surface on steep grades.

The length of life on any gravel road will depend on how carefully it is built, with what character of gravel it is surfaced, the amount and character of travel, and the system of maintenance.

(See Plates IX, X, XI, XII, XIII, XIV, XV.)



Gravel road, Montgomery County. Court street road two and a half miles from center of city. Road built over black prairie soil with



Gravel road, Montgomery County, near City of Montgomery. This road is ten years old.

Union Academy and Ada gravel road, Montgomery County. (Old [illegible]

Tuscaloosa-Birmingham road, two miles from Tuscaloosa. The banks along the road here are made of Lafayette gravel and loam, the materials from which the road is constructed.

[illegible] Just out of Florence, Lauderdale County, made of "creek gravel" (Fort Payne chert.)

PRACTICAL SUGGESTIONS ON SAND-CLAY ROAD CONSTRUCTION.

By W. S. Keller, State Highway Engineer.

In the preparation of this article on a subject which has been so ably treated in bulletins by the U. S. Office of Public Roads, the author is conscious of his limitations and does not attempt to write a text-book, or theoretical article, but simply a statement of what sand-clay roads are, and how they can be built.

Every farmer who lives in a section of country where both sand and clay are prevalent, is more than likely traveling over a section of natural sand-clay road and still, more likely, is ignorant of the fact. He can no doubt call to mind some particular spot on the road he travels, though it may not be more than 100 feet in length, that is always good and rarely requires the attention of the road hands. Good drainage will be noticed at this place and if he takes the trouble to investigate, he, no doubt, will find that a good mixture of sand and clay forms the wearing surface. If this 100 feet of road is always good, then why can't the entire road be made like it? It can, provided man will take advantage of the lesson taught by nature, and grade the road so that drainage will be good, and surface the balance of the road with the same material. If it is not possible to find this ready mixed surfacing material convenient to the road to be surfaced, it may be possible to find the two ingredients in close proximity. In case the road has a predominatingly sandy character clay should be added or in case clay predominates, sand should be added to produce good results.

There are four general ways in which sand-clay roads may be built:

1. Ready mixed sand and clay placed on clay, sand or ordinary foundation.
2. Sand and clay placed on soil foundation and mixed.
3. Clay hauled on a sand foundation and mixed with the sand.

4. Sand hauled on a clay foundation and mixed with the clay.

Taking the various methods up in order:

First: A natural mixture of sand and clay can nearly always be found where, as stated before, the two properties are found separate. The most important point is, to know the natural mixture when seen. The very best guide to this is to be had from the observation of roads in the immediate vicinity and to find a natural piece of good road. This accomplished a sample taken from the best of this good section, will by comparison, enable you to find what is required, close to the road to be surfaced. This natural mixture of sand and clay can be noticed in any section of the State where red clay and sand are found cropping out, usually well up in the hills, having in ditches and cuts the appearance of red sandstone. A real good stratum of well mixed sand and clay will stand perpendicular in cuts and ditches resisting erosion almost as well as sandstone. A list of the best natural sand-clay mixtures will show the sand forms about 70 per cent. of the whole. The test is very simple. Take an ordinary medicine glass, measure two ounces of the mixture into a glass and wash out the clay. Dry the remaining sand and measure again in the medicine glass. Of course the loss will be the amount of clay originally contained in the mass. The theory of the sand-clay mixture as a road building material is, that the clay fills the voids between the grains of sand, firmly binding them together. The sand forms the wearing surface. In other words we may say that the clay is the binder and the sand is the wearing surface.

After the material is found, the process of building the road is simple: Before placing any sand-clay on the road, the road should be graded the desired width. I prefer to have a good width for the crown of the road before grading, say 24 feet exclusive of side ditches, which are usually about 3 feet wide each. Sand-clay is cheap, and I would advise that 16 feet of the grade width, (24 feet), be surfaced. This will leave 4 or 5 feet shoulder on either side. The surface of the graded road should be flat or slightly convex. The sand-clay should be put on from 8 to 12 inches in thickness, depending on the character of the sub-grade or formation. Where you have a hard-clay for foundation 8 inches of sand-clay will suffice. If the sub-grade is sand, it is well to put on as much as 12 inches of the surfacing material. After a few hundred feet of surface material has been placed, a grading machine should be run over it to smooth and crown the road surface before the top becomes hard and resists the cutting of the blade. It is a good plan to turn the blade of the machine so as to trim the edges of the surfaced part, discharging the excess sand and clay onto the earth shoulders. After one round trip with the blade turned out, the remaining dress work with machine should be with blade turned in with exception of one trip down center of road with blade at right angle to the axis of the road for the purpose of distributing any excess of material left in the center.

After the machine work, it is well to follow with a split-log drag, which smoothes any rough places left by the machine and leaves the road with a smooth, even surface. It must be borne in mind that a sand-clay road, unlike other roads, cannot be finished in a short space of time. It can of course be thus left in apparently a finished condition with a hard smooth surface, but it will be found on close examination that the hard surface is in reality only a crust underneath which there are several inches of loose material. After the first hard rain the crust softens, the road gets bad and the work appears to be a failure. This slumping of the road, however, is just what is needed to make it eventually good. After the surface has dried until the mass is in a plastic state, it should be dragged until the surface is once more smooth with proper crown and should be kept this way by dragging at least once a day until the sun has baked it hard and firm. The mistake of keeping traffic off during this process of resetting should not be made. The continuous tamping of the wheels of wagons and hoofs of horses is just what is needed to compact the sand-clay into a homogeneous mass. The ordinary roller is not very effective in this work, however, it would appear that a tamping roller, such as has been used in the construction of the oil roads of California, would be very effective. A split log drag is an indispensible machine in the construction of any kind of sand-clay road.

Second: Sand and clay placed on a soil foundation and mixed. This is necessary where the old road has neither a clay or sand foundation and it is impossible to find the two ingredients ready mixed, but possible to geth both in separate state near at hand. The clay should first be placed on the road to a depth of 4 inches and the required width. It is not wise to place more than a few hundred lineal feet of clay before the sand is hauled, as the clay rapidly hardens and makes the mixing process difficult. After, we will say, 400 feet of clay has been placed, the clay should be broken by means of a plow and harrow, if it has become hard, and sand to a depth of 6 inches placed on it. This should be plowed and harrowed in thoroughly. This is best done immediately following a rain as the two can be more satisfactorily mixed. Traffic aids the mixing and should be encouraged on the road. After the mass appears to be well mixed the road should be properly shaped as previously explained. The road should be given watchful attention and, should sand or mud holes appear, a second plowing and mixing should be given it.

Third: Clay hauled on a sand foundation and mixed with the sand. The mixing process is similar to that described under second head. It is only necessary to add that, as the foundation is sand, a little more clay will be necessary than where the foundation is of clay or soil.

Fourth: Sand hauled on a clay foundation and mixed with clay. The clay foundation should be plowed to a depth of 4 inches and harrowed with a disk or tooth harrow until lumps are thoroughly broken or pulverized. Sand should then be added to a depth of 6 inches and mixed as before described.

Sand and clay can be mixed best when wet, but as most road construction is done in the summer months, it rarely rains just when you are ready, so we are compelled to do most of the

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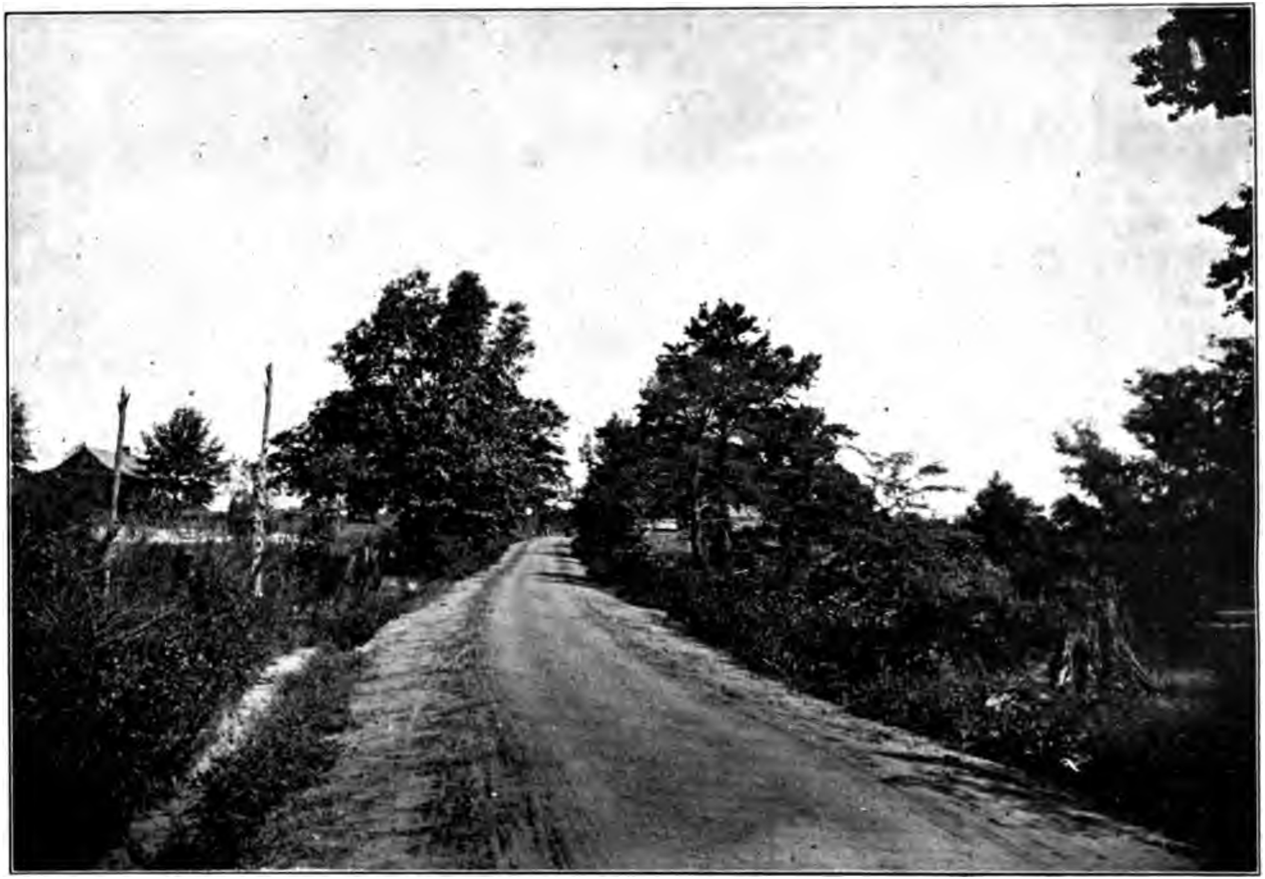
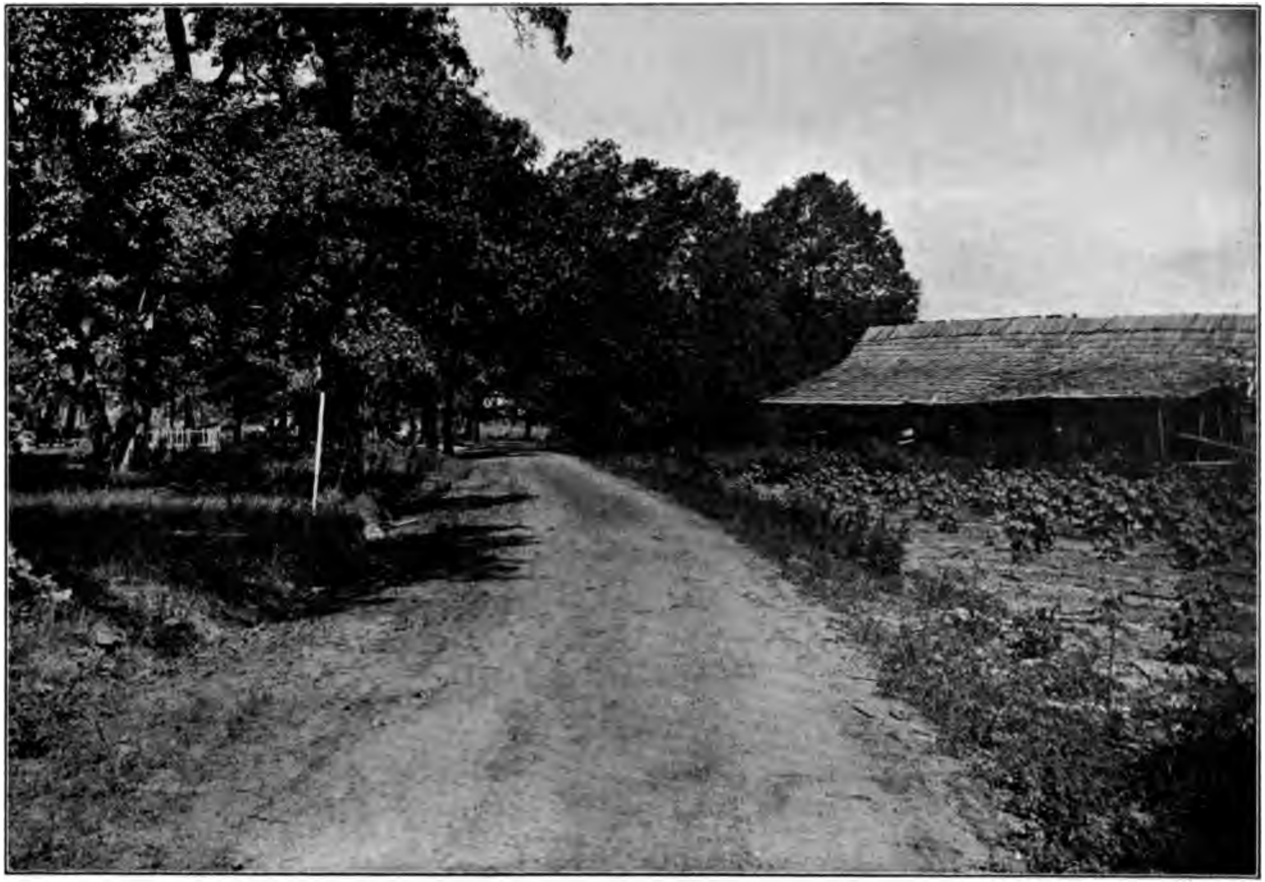


Pike County sand-clay road. Scene about three and one-half miles from Troy, on Troy and Elba road. View looking towards Troy.



Pike County sand-clay road Scene five miles from Troy on Troy and Ozark road View looking towards Troy

mixing dry and keep the road in shape after the first two or three rains, while the passing wagons and vehicles give the road a final wet mixing. The cost of sand-clay roads, like any other kind, varies greatly, depending on the character of grading and the proximity to the road under construction of the surfacing material. Good sand-clay roads can be built from $500 to $1,500 per mile. In some places where underneath a five or six inch surface of sand, a good sand-clay is to be found and this is on a level stretch of road,, by means of a large grading plow and machine, turning the sand under and shaping the road up, a mile can be built for $250 or $300.

A sand-clay road is the cheapest road to maintain for the reason that it can be repaired with its own material. By this I mean that with a split log drag or grading machine ruts can be filled with material scraped from the edges, whereas on gravel or macadam roads, such is not possible. The repairing of these roads can be done almost exclusively with the split-log drag, only enough hand work being required to keep the gutters open and growth of weeds cut on the shoulders.

Those contemplating the construction of sand-clay roads or any other kind of roads should bear in mind that in road construction, more so perhaps than in any other kind of work, does the old adage of "What is worth doing is worth doing well," apply.

(See Plates XVI, XVII, XVIII.)

EARTH ROADS.

By Wm. F. Prouty.

More than 96 per cent. of the roads of Alabama are unimproved and belong to the type known commonly as earth roads. Over this class of road still moves a great percentage of all our traffic, and doubtless this will be the condition for many years to come. It is consequently logical that the welfare of the earth road should receive the first and the most important consideration. As it stands today, however, the earth road is perhaps the mot abused and neglected of all our public highways.

The orinary country road is, as a rule, either a sand or a clay road, or a mixture of the two in some proportion. The methods of construction and maintenance of a sandy road are radically different from that of one made of clay. This is so because the action of water on the two is radically different. Moisture improves the sandy road but greatly injures the one made of clay.

The sand-clay road which blends the good qualities of both clay and sand, is not infrequently found in nature, and its artificial construction is most earnestly recommended for country districts. (The subject of sand-clay roads is treated elsewhere in the bulletin.)

The most important thing in the construction of any road is its location. It is the only permanent thing about it. Upon location depends the grade, which in turn regulates the rate of erosion and the amount of load which it is possible for a team to haul. (Plate XIX.)

*The second most important thing in connection with the construction of a road is its drainage. Because of the different actions of moisture on sand and on clay we find that different rules apply both to the location and the drainage of roads made from these different materials. A sandy road should be

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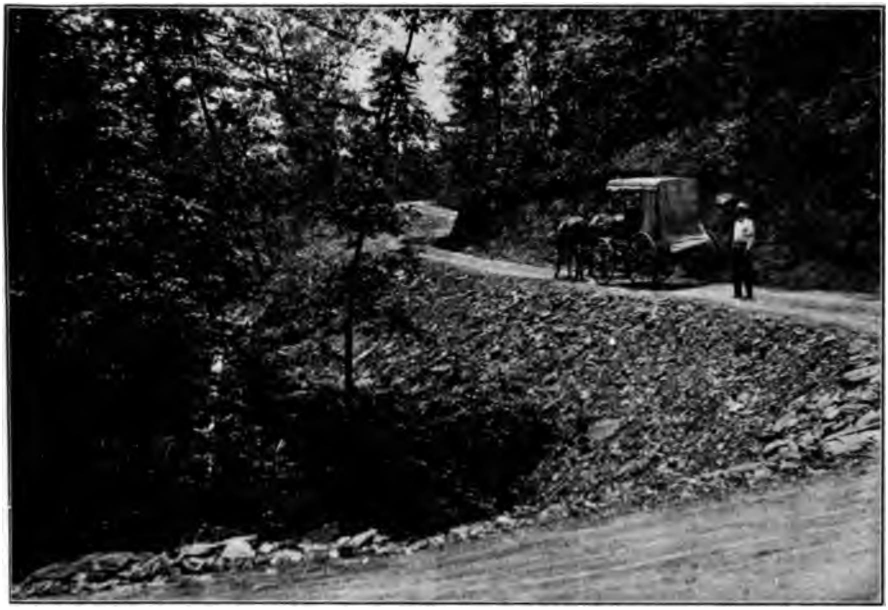
*See Chapters on location of roads and on drainage of roads.



New graded earth road through carboniferous shales and sandstones, one mile west of Cordova, Walker County. This road replaces one which is twice as steep and practically as long.

kept as moist as possible, since in that condition it is much firmer and offers much less resistence to traction. The moisture may be maintained in the sandy road for a considerable part of the year by having the road bed lower than the sides of the road so that the ground-water may stand higher relative to the road, than is usually the case in the ordinary shaped road.

The less the sunlight on a sandy road the better. Thus it is usually best that a sandy road be located on the northern rather than on the southern slopes, if there is a choice, and in wooded areas rather than in open ground.

A clay road should be kept dry to be in the best condition, and consequently the road should be so located as to receive the maximum amount of sunlight, as would be the case on the southern slopes of hills, and away from the shades of trees and the moisture gathering influence of humus. The ground-water level should be kept well below the road bed, and the road should have a crown sufficient to quickly shed the water which falls on it. Smoothness of the road surface is here also very essential since holes or ruts catch and retain the rain water thereby softening the road.

In order to keep a road in good condition where there is an increased percentage of clay, the crown must be steeper, the surface smoother, the ground-water level lower, and the amount of sunlight received greater.

Of the two extreme types of the earth road, the sand and clay, the sand road can be much more neglected and still be passable, but it can never be a good road. While the clay road requires much more care to keep it in a passable condition, it is at the same time capable of being made into a much better road.

Concerning the construction of earth roads Mr. W. S. Keller, the State Highway Engineer, says as follows:* "Very few earth roads have in the true sense been constructed. The average road is opened without regard to grade or proper location and simply because it is desirous to have it pass A, B and C's houses. The opening consists in cutting down any trees or brush that can't be avoided by crooks and bends, leaving the stumps just high enough to allow wagons to pass over and requiring expert driving to miss. This highway is then ready for traffic. Unfortunately homes have been built and improvements made near and abutting these old roads to such an extent, that it is detrimental to such property to make any great change in location, or rectify bad allignment and grades. Of course beneficial changes can be made in many places that will be an advantage, not alone to the road but to the abutting propertly.

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*From paper read before the National Good Roads Association, Birmingham, May, 1911.

"In the reconstruction of an old earth highway the proper officer should first go over the road noting the changes that should be made. He should bear in mind especially: initial cost, cost of maintenance, the allignment and the grade. The centre line of the road should be established by an engineer if it is possible to secure one. If an engineer cannot be secured, the ordinary method of lining a fence can be used; that is, by means of sight poles. After the centre line has been established and width of road agreed on, you are ready for construction work. The proper and efficient grading force for this work should consist of a foreman, eight or ten good two-horse teams and drivers, one wheel and one drag scrape for each team, and one extra wheeler and drag for emergencies, one good railroad grading plow, one grading machine, one split-log drag, one dump man and one loader with five or six extra men for grubbing and other work. The foreman should be an experienced grading man who understands handling earth and knows when it is proper to use drag scraps, wheel scrapes or wagons. The road should be so graded that the ditches or gutters are parallel with the centre line of the road and of equal distance from it. When completed the road should be uniform in width and the surface should be smooth and even, free from holes and high places and with a uniform crown having a fall of one inch to one foot, from centre to gutter. On grades this rate of fall should exceed that of the grade to such an extent that water will readily flow to ditches instead of down the road. Drain pipes should be freely used and no water should be allowed to flow over the road if it can be avoided. In some cases it is not practicable to build the road above high water. In such cases, danger signs should be posted, showing at what stage the water becomes too high to allow fording of the stream.

"We have in the South nearly every kind of soil, from sticky gumbo on the one hand to coarse sand on the other. The method used for improvement of road through a section of one will not do altogether for the other. The worst roads that we have in the South are in our rich and fertile prarie lands, where unfortunately, there is very little road building material to be found. This soil readily absorbs water and becomes very sticky after rain. It expands freely and dries rapidly when the sun shines, and becomes very hard under the tamping effect of team and vehicle. From observation and experience I have learned that these roads of all others, require a very high crown and the driving surface should be only wide enough to allow two vehicles to pass. If a prairie road is narrow with a fall of not les than one and one-half inches to the foot, water will shed rapidly to the ditches and the entire surface will dry out quickly. A road of this kind can be constructed quickly and at little expense, except where grades are to be reduced or bottoms filled. No earth road can be maintained in good condition unless it is so constructed as to drain well and unless it is kept free from ruts and holes."

The chief problem of interest to us in connection with the earth road after construction is maintenance, since it is upon maintenance that practically all the money is spent or thrown away for earth roads. Especially is this so in regard to the earth roads of a more clayey character. It is relative to this latter type of dirt road that I wish especially to call your attention. Here the elimination of water is the all important problem. This is done in two ways either by underground or by surface drainage. In the first case drainage is usually accomplished by longitudinal tile or rock drainage, and in the second case by a sufficient crown of road and lateral ditches.†

Any discussion concerning the maintenance of earth roads would be very incomplete without setting forth the utility of the split-log drag. The split-log drag or drag of similar efficiency, is neither a fad nor a political machine, although the politicians are strongly advocating it. It is the most useful and economical instrument yet invented for maintaining the earth road. *Statistics show that an extremely small number of the citizens of our State are taking advantage of this opportunity. If the road drag were systematically used throughout our country districts we would not only directly save many thousands of dollars annually by the reduction of the necessary road tax but we would also have dirt roads which would be far superior to the present ones. There is no question of the truthfulness of this statement.

The states using the split-log drag extensively have found that the cost per year per mile to keep the road in good condition through the use of this instrument after the roads have once been shaped up, is approximately $6.00. In the State of Alabama there is at the present spent per mile per year for road improvement and maintenance about $32.00. The saving of a split-log drag would obviously be very great since a large percentage of the earth roads of the State are of a clayey nature and are the ones which at present are the most costly to maintain.

If the road to be dragged is badly rutted or out of shape, or if it is too narrow with no ditches, the road should first be graded before the drag is used. As a rule, however, the roads will not require much of this preliminary shaping up since the drag itself opens the ditches and draws the earth toward the center of the road, thus crowning as well as smoothing it.

The crown of the loamy soil road should be approximately one inch per foot and of the clay road one and one-half inches per foot.

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†See chapter on drainage of earth roads.

*Statistics recently gathered from R. F. D. men of the State and also from county officials by the Alabama Geological Survey.

The purpose for using a drag on a road is to smooth the surface and maintain the crown. The clay from the traveled portion of a road becomes so fine through wear that it is practically impervious to water. If there are holes left in the road they hold the rain water for long periods, and the road becomes consequently softened and the ruts deepened. If, however, these holes are filled with clay and the surface of the road uniformly smeared with the impervious material, there is little chance for the rain water to penetrate or damage the road. The clay thus spread over the surface when it is wet (the dragging must be done when it rains or immediately after a rain while the road is soft), is baked by the sun into a hard coat that makes an excellent wearing surface. Traffic tends to compact this coat and to tamp the material into the former holes. With each dragging the road becomes harder and smoother and the effect of rain on it grows less and less.

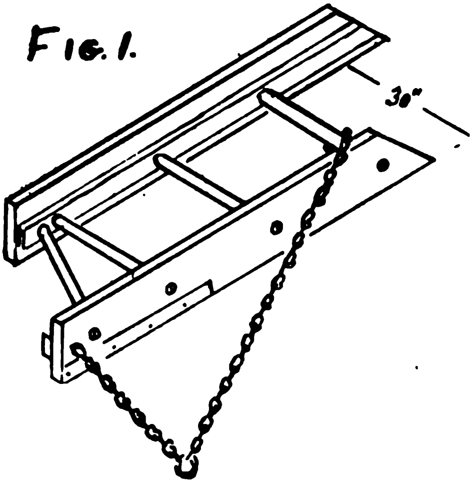
There are many kinds of home-made wooden drags which have been used with success. Figures 1 and 2 taken from Wisconsin Geological Survey publication, show the most common types with the general dimensions of each. Of the different types the split-log or the plank drag, made on the same general pattern, is perhaps the most useful and economical. The cost of the material for the drag should not be more than three or four dollars. In their construction a light weight wood rather than oak or hickory should be used, as it is much more easily handled and equally as efficient. There are also a large number of excellent drags of different styles which can be purchased at relatively small cost.

Roads properly dragged will dry out much earlier in the spring than they otherwise would, and since they are less rutted during the winter will also be much smoother and harder when dried out.

Dragging should be more frequent during winter and spring than in summer, but twice a month on an average is usually sufficient to keep the road in good condition.

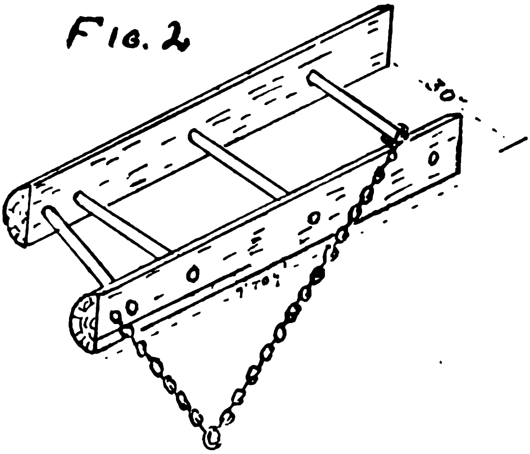
The following practical instructions for dragging are taken from the first report of the Illinois Highway Commission:

Fig. 1.



PLANK DRAG.

Fig. 2.



SPLIT-LOG DRAG.

"Make a light drag, which is hauled over the road at an angle so that a small amount of earth is pushed to the center of the road.

Drive the team at a walk.

Ride on the drag; do not walk.

Begin at one side of the road, returning on the opposite side.

Drag the road as soon after every rain as possible, but not when the mud is in such a condition as to stick to the drag.

Do not drag a dry road.

Drag whenever possible at all seasons of the year . If a road is dragged immediately before a cold spell it will freeze in a smooth condition.

The width of traveled way to be maintained by the drag should be from 18 to 20 feet; first drag a little more than the width of a single wheel track, then gradually increase until the desired width is obtained.

Always drag a little earth towards the center of the road until it is raised from 10 to 12 inches above the edge of the traveled way.

If the drag cuts in too much shorten the hitch.

The amount of earth that the drag will carry along can be very considerably controlled by the driver, according as he stands near the cutting end or away from it.

When the roads are first dragged after a very muddy spell the wagons should drive if possible to one side until the roadway has a chance to freeze or partially dry out.

The best results from dragging are obtained only by repeated applications.

Remember that constant attention is necessary to maintain an earth road in its best condition."

The following suggestions for using the drag are taken from the monthly bulletin of the Missouri Board of Agriculture for April, 1906:

1st. "The length of the chain, which is regulated by slipping it backward or forward through the hole in ditch end of drag. The length of the chain regulates the hold taken on the earth. To make the chain longer is equivalent to putting weight on the darg. If your drag is too heavy shorten the chain."

2nd. "The position of the snatch hook, which attaches the doubletrees. To move much dirt or cut small weeds hitch the hook close to the ditch end of the drag and stand as nearly on the end of the front slab as is safe. Drive very slowly when thus hitched. This one hitch seems to be the hardest to learn. The others suggest themselves.

3rd. "Position of the driver on the drag. To move dirt see above. In a soft spot stand on rear slab. On a hard spot stand on front slab and drive slowly. If the drag clogs with straw, weeds, sod or mud, step to a point as far as you can get from ditch end of the drag. To drop dirt in a low place step quickly from ditch end to other extreme. To fill a low place or mud hole nicely is the severest test of skill with a drag.

"I suspect you will become thoroughly disgusted when you first make the effort. But remember it will not be the fault of the drag if you fail.

4th. "Presence or absence and sharpness or dullness of the steel. The steel may project half an inch below the wood at the ditch end of the steel; but should come up flush with the wood at other end of the steel. After a clay or gumbo road has been dragged four or five years the soil becomes so tough and putty-like that one must study it closely to know what to do. Sometimes I use sharp endge of steel; sometimes dull edge (holes are bored in both edges of steel so that I can turn it up side down and use same bolt holes), and sometimes the plain wood.

"This can be learned only by experience and you have several years in which to study the problem.

"I hope these details and fancy points will discourage no one. Never forget that the poorest drag used in the poorest manner by a man who wants to learn will surely improve the highway."

There are numerous ways in which the work of dragging the road can be carried on. In some places the farmers living along the road, drag them in accordance with the instructions of the superintendent of roads. They are allowed a certain amount of time in which to do the work at a stipulated price per hour. In some places the farmers have organized to carry on the work for their own benefit without expense to the town. In some western cities the merchants have offered prizes for the best maintained road in their community by the use of the drag, thus encouraging the farmers to compete in the bettering of roads. (Good roads help the farmer and the merchant). Another plan, and one which seems to be more feasible than the others, is to contract with road superintendent to keep the roads in a given district in good condition by the use of the drag for so much per year.

The best recommendation the road drag can have is the fact that wherever it has been properly used on clay roads its use has been enthusiastically continued.

DUSTLESS ROADS AND BITUMINOUS BINDERS.

By Wm. F. Prouty.

The present tendencies in road construction are far different from what they were 10 years ago, and there has probably been no time in the history of road building, in the South, when the tendencies have been changing more rapidly than they are at the present time. The factors instrumental in causing this change of tendency in road construction and maintenance are many. Chief among them, however, should be mentioned the following: 1. Bond issues and money taxation make it possible to construct roads of greater initial cost and better class, and also to construct them more cheaply than it would have been possible with the older form of labor taxation. 2. The people are beginning to realize the great financial, social, and educational losses occasioned through bad roads. 3. The rapid development of automobile transportation has made absolutely essential hard smooth roads for their efficient use. The automobile men are more often the men of influence. 4. The rapid wear and the great amount of dust on certain classes of these hard, smooth roads is preventible by certain methods of treatment. 5. The public is awakening to the great nuisance and damage caused by dusty roads.

The most advanced step in the treatment or construction of roads is that which, besides making the road the most serviceable for the condition of traffic to which it is to be subjected, makes it also a relatively dustless road. It is this tendency to the construction of dustless roads to which I wish to call your attention.

There are a number of questions which naturally suggest themselves at this point such as: Where should dustless roads be built; how should dustless roads be built, and why should dustless roads be built?

We cannot hope to answer these questions with any degree of detail or exactness in this place, but it may be worth our while to give the subject a general kind of study.

The subject of dustless roads is not a new one. The dust nuisance has been recognized by cities for many years, and the city streets have been built with the thought in mind of having them yield as little dust as possible. Most cities also have watered, or otherwise treated their streets for many years to lay the dust where traffic has been heaviest, but not until within the last decade has much advance been made in the treatment of roads, other than city thoroughfares for the laying of dust. The automobile has been the chief agent whereby the advance along this line has been made. The amount of dust raised by teams is meagre in comparison with the amount raised by the swiftly moving automobile. Discomfort, danger to health, and damage to property along the dusty roads have each been a factor in influencing the public to rid themselves of this costly nuisance.

The public cannot hope to make any large percentage of the roads of a dustless nature, nor is that at present necessary, but the roads of the suburbs and the great public thoroughfares, which are daily receiving a large amount of traffic, especially by the automobile, must be treated to lessen the dust evil, if we are to work at all for our own and the public welfare.

Each community must settle for itself what roads should be treated to make them less dusty. The extent of the work is limited in the reverse ratio of wealth and enterprise of the people. This phase of the subject is not open, then, to discussion except to urge that the people fully awaken to the harmful effect to health and property of the dust and to bend every effort to eradicate the nuisance as far as possible.

There is no absolutely dustless road that will remain so for any great length of time, for if fine material does not come from the road itself it will, to some extent, come from extraneous localities. The term dustless must then be used in a relative sense and not in the absolute.

How can dustless roads be obtained is the question that most concerns the practical man. There are two possible methods.

1. By laying the dust that forms.
2. By preventing the formation of dust.

In the first method water or oil are added by some process to the dusty surface, and the dust particles are held by the surface tension or the cohesion of the liquid. The efficiency of this treatment varies largely with the viscosity of the liquid used and its liability to absorption or evaporation.

Water can be but temporary as it is highly volatile. The hygroscopic salts, those which have the power of gathering moisture from the atmosphere, as well as the lighter oils, are each also more or less temporary as dust layers.

In the second method the material used is such that its wear is very slight, or else it is composed of a substance which does not pulverize, and consequently does not yield dust. Here we deal either with the higher priced material for paving, such as brick, block, cement, etc., or else the heavier bituminous mixtures.

For the benefit of those who are contemplating either the palliation of dust on the roads or the construction of dustless roads, I shall attempt to brefly discuss some of the methods and materials used for this purpose.

The materials naturally group themselves, as already suggested, into those which are of a temporary nature and into those of a more lasting character. In the first class belong such materials as are effective for one season, or only a part of one season. Such materials are easily volatile in their nature, and, if one of the oils, has a low viscosity.

WATER.

For many years water was the only one of this class of dust layers which was used to any considerable extent, but with the introduction of oils the percentage of streets treated with water has considerably decreased. It is apparent that in some cases the true economic value of water as a dust layer has been lost sight of in the development of other dust palliatives. If the same study were given to the economical use of water that is now being given to oiling, the cost of using it would, I am sure, be considerably lowered. Some of the more enterprising cities are now watering the streets from tank cars on their electric lines, thus greatly reducing the cost of application along those streets.

It is very difficult to get cost data concerning the use of water as a dust layer because of the lack of records, but an average of several records which are at hand, taken in different places in the country, shows an average cost of from two and one-half to four cents per square yard per season.

HYGROSCOPIC SALTS.

Hygroscopic salts which are produced in large quantities by some of the chemical establishments in this country, have been used to no small extent in various states, especially in those states where freight on the salt is not too excessive. The results, as a rule, have been successful. One of the hygroscopic salts which perhaps is used more widely than any other, is calcium chloride.

This class of dust layers can be placed on the road either in solution from a sprinkling cart, or else in a dry form by hand or machine. The amount used, in case of calcium chloride, is one and one-half pounds per square yard per treatment. The action of the salt is to gather moisture from the atmosphere, and one treatment is sufficient to supply moisture to the road sufficient for laying the dust for a period of from two to three months, depending of course on weather conditions. The cost per ton of the calcium chloride is about $13.00 F. O. B. at the manufacturers. The cost of spreading the material is small. In Washington, D. C., the cost per square yard per season for laying the dust by this salt was four cents in 1910. In Albany, N. Y., for the same year, it is estimated to have cost less than water.

There are practically no injurious results from the use of this salt, and where it can be as cheaply employed as water its use is preferable because of the less frequent interval of its application and the consequent less obstruction to traffic.

EMULSIONS.

The application of oily substances as dust layers, through the medium of emulsion, has been tried with varying success. Many experiments have shown emulsion to be highly economical and effective. Petroleum, tars, etc., are also miscible with water through the action of a saponifying agent, or soap.

Many kinds of emulsions are now manufactured. Their application is by means of the sprinkling cart.

*Cost data for emulsified road oils is here presented from a number of cities for the summer season of 1910:

Montclair, N. J., cost per square yard per season, less than water.

New London, Conn., cost per square yard, per season, 25 per cent. more than water.

Waltham, Mass., cost per square yard per season, 2 1-4c, water costs 3c.

Buffalo, N. Y., cost per square yard per season, 1.78c, on macadam.

Boston, Mass., cost per square yard per season, 1.7c., 8 applications.

Springfield, Mass., cost per square yard per season, 2c for 7 1-2 months.

"In binding the dust on the street pavements, experiments have been made in various parts of Berlin with a particular preparation, and according to official report a sprinkling with a 1 to 100 solution of this preparation and water, by means of ordinary street sprinklers, successfully kept the dust bound, even in the streets with the largest traffic, for four to five weeks. The cost per square meter (1.196 yards) for six oil solution sprinklings a year was less than one-seventh of the average annual cost for water sprinkling."

It will thus be seen that as a rule the general cost for treatment by emulsified oils is less than by sprinkling with water. There is also an accumulative beneficial effect provided the oil used is an asphaltic oil, so that the cost for the second year should be somewhat less than for the first.

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*Data from Good Roads Magazine March and May, 1911.

HEAVIER BITUMINOUS MATERIALS.

Of the heavier bituminous materials which have been used in the United States in the past few years for bituminous road construction we have the following classes: fluxed native asphalts, oil asphalts, residual asphalts and semi-asphaltic oils, light oils, coke-oven tars, coal-gas tars and combinations of coal-gas tars and water-gas tars, combinations of asphaltic materials and tars.

The characteristics of these and also the definitions of many terms relative to the production of oils and residums is to be found in Circular No. 93 of the Office of Public Roads 1911. (See also bibliography of road literature in the appendix for further references.)

From the investigation of the last few years it is evident that refined coal tar is much to be preferred to the crude coal tar as a binder, it is also shown that crude water-gas tar is valuable only as a temporary binder and that its most satisfactory use is as a dust layer. Light applications of it should be sprinkled on the road whenever the dust becomes excessive.

The following table* shows the amounts of the three larger classes of bituminous binders used during 1908, 1909 and 1910 in eight of the states which have had the greatest amount of experience in the use of bituminous binders, viz.: Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania and Rhode Island:

Superficial Treatment of Roads.

	Tars and Tar-Asphalt Compounds.	Fluxed Native Asphalts, Oil Asphalts and Residual Asphaltic and Semiasphaltic Oils.	Light Oils.
1908	57,700 sq. yds.	239,500 sq. yds.	—
1909	95.500 sq. yds.	910,600 sq. yds.	4,125,900 sq. yds.
1910	123.400 sq. yds.	2,434,200 sq. yds.	9,890,400 sq. yds.

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*Mr. A. H. Blanchard, Good Roads Magazine, April 1911.

Bituminous Pavements Constructed by Penetration Methods.

	Tars and Tar-Asphalt Compounds.	Fluxed Native Asphalts, Oil Asphalts and Residual Asphaltic and Semiasphaltic Oils.	Light Oils.
1908	37,800 sq. yds.	25,200 sq. yds.	———
1909	170,200 sq. yds.	2,077,400 sq. yds.	———
1910	339,300 sq. yds.	4,840,200 sq. yds.	26,500 sq. yds.

Bituminous Pavements Constructed by Mixing Methods.

	Tars and Tar-Asphalt Compounds.	Fluxed Native Asphalts, Oil Asphalts and Residual Asphaltic and Semiasphaltic Oils.	Light Oils.
1908	52,100 sq. yds.	4,400 sq. yds.	———
1909	136,000 sq. yds.	219,500 sq. yds.	———
1910	158,000 sq. yds.	432,600 sq. yds.	———

It is interesting to note from the standpoint of the general increase in the use of bituminous materials in the states cited that in 1908 bituminous materials were employed in the construction and maintenance of 416,000 square yards of road surface, in 1909 of 7,734 square yards and in 1910 of 18,244,000 square yards

The present tendencies as to the kind of bituminous binders used and the methods of applying them is briefly summarized by Mr. A. H. Blanchard in a paper read before the American Association for the Advancement of Science, 1910:

Surface Treatment.

"In the surface treatment of macadam and gravel roads several lines of development have been especially noticed: first, a more general use of refined coal gas and water gas tars in place of crude tars; second, an extraordinary increase in the various kinds of asphaltic oils, combined with sand, gravel or stone chips to form a carpet wearing surface; third, an increase in the use of light oils for the purpose of allaying dust on state roads and thus, to a certain extent, preserving the surface of the road by the retention of the top dressing;

fourth, a substitution of mechanical distributors of both the pressure and gravity flow type in place of hand application methods.

The practice of the past three years has amply demonstrated that the success of superficial tarring is dependent upon the recognition and adoption of those fundamental principles which were layed down by the French engineers in 1903. As those principles have not been adopted in many instances in the United States, they will be given here in brief. First, superficial tarring should be done only during dry and warm weather in order to obtain efficient and economical results; second, the road must have a dry, smooth and durable surface; third, all dust must be thoroughly brushed off in order to facilitate the adherence of the tar; fourth, after the distribution of the coat of tar it is necessary, in order to avoid a slippery surface, to apply a dressing of sand, gravel or stone chips. The practice of some prominent English engineers does not include the adoption of the fourth recommendation cited, as it is maintained that a top dressing is not an essential element of a non-slippery tarred surface.

A well developed plan of annually treating certain roads of a system with a thin coat of bituminous material is being adopted by certain states. This practice embodies the recognition of the fundamental principles of economy and efficiency in modern highway construction; namely, the adaptation of method and material to local conditions."

Penetration Method.

"In connection with the use of bituminous materials by penetration methods, certain noteworthy tendencies are apparent. Most important are the employment of distributing apparatus and the formation of broken stone courses in such a manner as to endeavor to secure the maximum uniformity of distribution of material and the definite limitation of penetration.

The unfortunate delay in the application of the penetration method due to damp stone, has been overcome in some instances by the employment of mechanical surface heaters.

A modification of the penetration method is known as the "puddling method." The top course in this case is filled with screenings puddled by watering and thoroughly rolled. After the surface dries out it is picked up. The bituminous material is then applied, a coat of chips is spread and the surface rolled. After the surplus chips are brushed off, a flush coat of bituminous material is applied. The application of another coat of chips and a final rolling completes the process.

Another modification of the regular penetration method has been employed during 1910. In this method the foundation is thoroughly filled and rolled. A layer of sand is spread upon the foundation course to a depth of about an inch. Refined tar, heated to about 250° F. is then applied to the coat of sand. The top course, composed of broken stone varying from three-fourths to 2 3-4 inches is spread and rolled, the lower voids being filled with the bituminous mastic. After consolidation a second coat of refined tar is applied. As soon as possible after spreading the second coat of tar a layer of stone chips is spread and rolled. A third coat of refined tar is then applied and the surface finished by rolling a covering of screenings or sand."

Reconstructed Oil Roads.

"In the reconstruction of old roads there has been a general employment of the method of picking up the old surface to a depth of 2 inches to 4 inches by the use of mechanical scarifiers, placing a thin coat of new metal on the loosened surface, and then constructing a bituminous pavement by the penetration method.

In both the construction and reconstruction of roads by penetration methods the surface is finished in various ways. One method is to spread a coat of chips or sand after the first coat of bituminous material is applied, roll thoroughly, and after the road has set up sufficiently, open it to traffic. Another method is to apply a second coat of bituminous material before the application of a layer of chips. The bituminous material for the flush coat may or may not be the same as used for the first coat. A layer of chips or sand is then spread over the flush coat and thoroughly rolled. A third method is essentially the same as the second cited except that a layer of chips is applied to the first coat of bituminous material, thoroughly rolled and the surplus chips brushed off before the application of the flush coat of bituminous material."

Character of Material Used.

"From the standpoint of the character of bituminous material used it is of special interest to note the increased use, particularly in 1909 and 1910, of fluxed natural asphalts and oil asphalts especially manufactured for application to unheated crusher run stone."

Mixing Method.

"In the construction of bituminous pavements by the mixing method a number of improvements and developments should be noted. Some attention has been paid to having the stone dry and reasonably clean. Although advantages accruing by using clean and dry stone are recognized, the practice has been far from satisfactory, only very crude methods having been thus far employed. The practice of heating stone on plates has been used to a certain extent with deleterious results. In a few cases mixing machines and tar coating machines have been employed in connection with the construction of bituminous pavements which are to cost not over $0.90 to $1.00 per square yard. The types of mixers which have been used to date are more or less unsatisfactory, especially when bituminous materials are used which are solid at ordinary temperatures or which flow with considerable difficulty when cold. During the season of 1911 considerable development should take place in the heating of stone by mechanical dryers and also in the use of new types of mixers especially manufactured for the purpose of mixing bituminous materials with a mineral aggregate.

In various parts of the United States sand, gravel and earth have been mixed in place by various processes with bituminous materials in the endeavor to form an impervious, dustless and durable road surface. This work is being watched with considerable interest as the utilization of local materials for the aggregate in many instances reduces the cost of construction materially. The limitation in the weight of traffic to be carried throughout the year under all climatic conditions is one of the most important points under discussion at the present time in connection with the above methods.

A new type of construction recently introduced by Logan Waller Page, director of the United States Office of Public Roads, is known as oil cement concrete. In this process fluid residual petroleum is added to the usual ingredients composing concrete.

From the standpoint of the nature of the materials used, again it is noted that there is an increase in the use of refined tar, considerable employment of heavy asphaltic compounds and also the employment of combinations of tar and asphalt, the most noticeable increase, however, being in the use of heavy asphaltic oils which can be mixed readily with broken stone as it comes from the crusher.

There has been a marked tendency on the part of highway engineers during the past three years to appreciate more fully the importance of the various chemical and physical properties of bituminous materials. Many engineers and manufacturers now wisely advocate using different grades of the same type of bituminous material for varying local conditions and for different methods of bituminous construction. During 1909 and 1910 bituminous materials for use in the construction and maintenance of roads have been purchased in two ways; namely, by buying direct from the manufacturer a product known under a trade name and by purchasing the material under specifications. The old custom of simply purchasing bituminous material under a trade name without investigation of its properties is being replaced by the second method. The object of the second method has been to cover one or more of the following points:

First, to secure uniformity in the material furnished for a given contract; second, to obtain a compound which conforms to certain requirements with reference to the chemical and physical properties of the material which are considered essential; third, to provide a standard by which it is hoped that a satisfactory material may be duplicated on other contracts. The effect of the various physical and chemical properties of bituminous materials on their value as road binders is being investigated by a special committee of the American Society of Civil Engineers. Standard methods of testing bituminous materials is the subject of investigation by a sub-committee of the American Society for Testing Materials."

The experiments of the U. S. Office of Public Roads during 1910 with bituminous binders is especially interesting. The results of these experiments are to be found in Circular No. 94 of that Office. The experiments conducted at Knoxville, Tenn., are perhaps of the greatest benefit to us, since the conditions there of labor and cost of materials are more nearly like our own than in places farther north and west. The work on the experimental roads at Knoxville began July 25 and ended September 7. The road constructed was bituminous macadam using the penetration method. The bituminous material was poured from coal scuttles fitted with strips of metal across the spouts so as to give an opening 4 1-2 inches across and 1-4 inch wide. The bituminous material was heated in two 120 gallon unmounted kettles, which was found to be a more expensive method than heating in kettles, where a fire box was used. Refined tar and oil asphalt were used on the respective sections. The foundation of the road was prepared from an old road which was very uneven. It was first spiked by a steam road roller then graded by a road machine, a spiked-tooth harrow was then run over the road bringing the larger stones to the surface and working the finer material down. Crushed limestone was next added, ranging from two inches to 3-4 inch in diameter to a depth of two inches then rolled until firm. A crown of 1-2 inch to the foot was adopted for both foundation and bituminous wearing surface. The labor employed was unskilled, consisting mainly of negroes. Common labor for foundation work cost $1.35 per day of ten hours, and for bituminous work, $1.50 per day of ten hours. Double teams cost $3.50 and the roller and operator $3.00 per day. The analyses of the three preparations used were as follows:

Table Showing analysis of refined coal tar[1] *used in experiment No.* 1.

Specific gravity 25°/25° C	1.249
Float test at 32° C. (time)	1′ 47″
Float test at 50° C. (time)	44″
Per cent of free carbon (insoluble in CS_2, air temperature)	26.31

Distillation:

	Per ct. by vol.	Per ct. by w't.
Water	Trace.	Trace.
First light oils to 110° C	0.4	0.2
Second light oils 110°-170° C	[2] 2.2	1.6
Dead oils 170°-270° C	[3] 24.9	20.0
Pitch residue	[4] 72.5	77.7
	100.0	99.5

[1] Viscous, fluid, sticky. [2] Turbid. [3] Distillate showed about one-half its volume precipitated solids when cold. [4] Hard, brittle, dull fracture.

Table showing analysis of refined tar preparation[1] *used in experiment No.* 2.

Specific gravity 25°/25° C	1.244
Float test at 50° C. (time)	4′ 29″
Per cent of free carbon (insoluble in CS_2, air temperature)	17.13

Distillation:

	Per ct. by vol.	Per ct. by w't.
Water	0.0	0.0
First light oils to 110° C	.0	.0
Second light oils 110°-170° C	[2] .4	.3
Dead oils 170°-270° C	[3] 23.2	18.8
Pitch residue	[4] 76.4	80.4
	100.0	99.5

Table showing analysis of oil-asphalt[5] used in experiment No. 8.

Specific gravity 25°/25° C	0.998
Penetration (No. 2 N, 5 seconds, 100 grams, 25° C.)	86°
Per cent of gain at 163° C., 5 hours (20 grams)	0.02
Penetration of residue[6] (as above)	75°
Per cent of total bitumen insoluble in 86° B. paraffin naphtha	22.88
Per cent of fixed carbon	13.78
Per cent of bitumen soluble in CS_2, air temp. (total bitumen)	99.85
Organic matter insoluble	.10
Inorganic matter	.05
	100.00

[1] Very viscous, sticky. [2] Clear. [3] Distillate showed about two-fifths its volume precipitated solids when cold. [4] Hard, fairly lustrous. [5] Semisolid, sticky. [6] Slightly harder, otherwise unchanged.

THE FOLLOWING IS THE TABLE SHOWING THE COST DATA IN CONDENSED FORM FOR THE THREE STRIPS OF EXPERIMENTAL ROAD:

Section No.	Description.			Quantity of material.				Cost data (cents per square yard).										Total cost—			
	Binding materials.	Length of section (feet).	Area of section (square yards).	No. 2 stone (cubic yards per square yard).	Screenings (cubic yards per square yard).	Binder, first application (gallons per square yard).	Binder, second application (gallons per square yard).	No. 2 stone at crusher.	Screenings at crusher.	Handling and laying stone.	Binder.	Hauling binder.	Heating and applying binder.	Rolling.	Grading.	Miscellaneous.	Freight on binder.	Cents (per square yard).	Entire section.	Foundation and wearing surface (cts. per sq. yd).	Entire section—foundation and wearing surface.
1-3	Foundation	980	2,198	0.054	......	......	......	[8]6.48	......	1.72	......	......	......	1.23	3.72	....	......	13.15	$289.04	.....	....
1	Refined coal tar	217	482	.117	0.022	1.49	0.50	7.90	1.48	8.90	21.89	0.36	2.78	1.27	......	2.31	0.00	46.89	226.01	60.04	$289.39
2	Refined tar preparation	590	1,311	.117	.022	1.21	.50	7.90	1.48	8.30	10.26	.19	3.24	.80	......	2.31	5.75	40.83	535.28	53.98	707.68
3	Oil-asphalt	173	[7] .405	.117	.022	1.69	.50	7.90	1.48	8.90	16.10	.00	2.96	.91	......	2.31	.00	40.56	164.27	53.71	217.53

[7] Includes intersection of Lake Street. [8] No. 2 Stone at siding.

It will be noticed that the cost ranges from about 53 to about 60 cents per square yard, including all expenses on foundation and materials.

During the year 1910 extensive experiments were also carried on at Ithaca, N. Y. Here as at Knoxville an old road was spiked up, graded and treated with broken stones which when rolled was about 2 1-2 inches thick. Three different methods were used, viz: 1st, the penetration method; 2nd, the prepared filler method, which may be described as one in which the wearing course of stone is bound with a filler composed of a mixture of stone screenings and bitumin and, 3rd, the mixing method. The expenses connected with the construction of the road for labor and material is somewhat in excess of that at Knoxville, Tenn. Labor cost $1.75 for a nine hour day and double teams $4.00 per day. The cost of construction was, as in the case of the experiment at Knoxville, rather excessive owing to the shortness of the sections and the crude machinery and heating apparatus. The different bituminous materials used were as follows: oil asphalt, refined asphaltic preparation, refined semiasphaltic oil, refined water-gas tar.

The following tables show the cost data for the different materials used in the three methods: 1. The penetration method. 2. The prepared filler; and 3, the mixing method. It will be seen that the total cost per square yard for the penetration method ranges from 63 cents to 79 cents, for the prepared filler method, from 82 cents to 92 cents, and for the mixing method from 91 cents to $1.13. For details of the various experiments at Ithaca, see Circular 92 and 94 of the Office of Public Roads.

Table showing materials and cost data of experiments at Ithaca, N. Y., 1910.

PENETRATION METHOD.

Description.			Quantity of materials.										Cost data (cents per square yard).												Total cost—			
Section No.	Binding materials.	Course.	Length of section (feet).	Area of section (square yards).	No. 2 stone (cubic yards per square yard).	Screenings (cubic yards per square yard).	Binder, first application (gallons per square yard).	Bonder, second application (gallons per square yard).	Screenings used on stone shoulders (cub. yds. per sq. yard).	Sand used on shoulders (cubic yards per square yard).	Sand filler (cubic yards per square yard).	3-4 inch stone used (cubic yards per square yard).	No. 2 stone at siding.	3-4 inch stone at siding.	Screenings at siding.	Hauling and laying stone.	Binder.	Hauling binder.	Heating and applying binder.	Rolling.	Miscellaneous.	Freight on binder.	Grading.	Hauling and spreading sand.	Cents (per square yard).	Entire section.	Foundation and wearing surface (cents per sq. yards).	Entire section—foundation and yearing surface.
16	Oil-asphalt..........	Foundation......	300	667	0.042	.....	....	....	0.025	.....	.....	.....	6.34	....	3.17	5.29	.....	.....	.....	3.09	1.30	.....	4.28	.....	23.47	$156.55	79.10	$421.61
16	Oil-asphalt..........	Wearing surface	300	533	.113	0.021	1.00	0.50	.....	.....	.....	.....	17.06	....	3.17	5.78	11.25	1.90	1.85	5.01	1.62	2.09	.....	.....	49.73	265.06		
26 27	Refined asphaltic preparation.	Foundation......	252	586	.....	.....	....	....	.025	0.016	.....	.....	.....	.....	.....	.....	.....	.....	.....	3.09	1.30	.....	4.28	0.03	8.70	50.08	....	....
26	......do...............	Wearing surface	106	308	.100	.034	.80	.80	.....	.....	0.021	0.024	15.10	3.62	5.13	8.19	18.40	1.01	6.76	5.01	1.62	3.70	.....	.03	69.36	213.63	78.34	241.28
27	......do...............	......do............	146	260	.100	.034	.80	.00	.....	.....	.021	.024	15.10	3.62	5.13	8.98	9.20	.51	3.38	5.01	1.62	1.85	.....	.03	54.43	141.52	63.40	164.86

Table showing materials and cost data of experiments at Ithaca, N. Y., 1910.—Continued.

PREPARED-FILLER METHOD.

Description.			Quantity of materials.										Cost data (cents per square yard).											Total cost—			
Section No.	Binding materials.	Course.	Length of section (feet).	Area of section (square yards).	No. 2 stone cubic yards per square yard).	Prepared filler, first application (cubic yards per sq. yard.)	Prepared filler, second application (cubic yds. per sq. yd.)	Screenings (cubic yards per square yard).	Binder in mixture, first application (gallons per sq. yd).	Binder in mixture, second application (gals. per sq. yd.	Binder in paint coat (gallons per square yards	Screenings used on shoulders (cubic yards per sq yd).	No. 2 stone at siding.	Mixed stone at siding.	Screenings at siding.	Binder.	Hauling and laying No. 2 stone.	Preparing and laying mixture.	Heat'g and applying paint coat.	Freight on binder.	Rolling.	Miscellaneous.	Grading.	Cents (per square yard).	Entire section.	Foundation and wear'g surface. Basis of wearing surface (cts. per square yard).	Entire section—foundation and wearing surface.
17	Oil-asphalt....	Foundation	50	111	0.042	.....	.....	.....	....	....	....	0.025	6.34	.....	3.17	.....	5.29	....	....	....	3.09	1.30	4.28	23.47	$26.05	83.69	$74.48
17	......do.........	Wearing surface ..	50	89	.111	0.042	.....	0.021	0.90	....	0.50	.....	16.76	6.34	3.17	10.50	5.78	3.40	1.50	1.93	5.01	....	.....	54.42	48.43		
19	......do.........	Foundation	76	169	.049	.....	.....	.....	....	....	....	.025	7.40	.....	3.17	.....	5.85	....	....	....	3.09	1.30	4.28	25.09	42.40	92.34	124.66
19	......do.........	Wearing surface ..	76	135	.111	.055	0.014	.021	.98	0.25	....	.....	16.76	10.42	3.17	14.15	3.37	5.59	....	2.46	5.01	....	.....	60.93	82.26		

Table showing materials and cost data of experiments at Ithaca, N. Y., 1910.—Continued.

MIXING METHOD.

Description.				Quantity of material.					Cost data (cents per square yard).														Total cost—			
Binding materials.	Course.	Length of section (feet).	Area of section (square yards).	No. 2 Stone (cubic yards per square yard).	Mixed stone (cubic yards per square yard).	Screenings (cubic yards per square yard).	Binder in mixture (gallons per square yard).	Binder used in paint coat (gallons per square yard.	Screenings used on stone shoulders (cubic yds. per sq. yd.	No. 2 stone at siding.	Stone used in mixture at siding.	Screenings at siding.	Hauling and laying stone.	Binder.	Hauling mixture.	Preparing and laying mixture.	Heating and applying paint coat.	Rolling.	Miscellaneous.	Freight on binder.	Grading.	Cents (per square yard).	Entire section.	Foundation and wear'g surface. Basis of wearing surface (cts. per square yard).	Entire section—foundation and wearing surface.
Oil-asphalt....................	Foundation	300	667	0.049	.....	.....	.....	.....	0.025	7.40	.....	3.17	5.85	.....	....	.....	....	3.09	1.30	....	4.28	25.09	$167.35	113.58	
......do........................	Wearing surface ..	300	533	.....	0.119	0.021	0.88	0.55	.....	.....	17.97	3.17	....	16.45	3.37	29.60	2.13	5.01	1.62	2.86	....	82.18	438.02		$605.37
Refined semiasphaltic oil.	Foundation	300	667	.054	.....	.....	.....	.....	.025	8.15	.....	3.17	6.24	.....	.....	.....	.....	3.09	1.30	....	4.28	26.23	174.95	....	....
......do........................	Wearing surface ..	206	366	.....	.113	.021	.83	.55	.....	.....	17.06	3.17	....	9.66	4.83	26.98	2.17	5.01	1.62	1.99	....	72.49	265.32	105.32	385.45
......do........................	...... do	94	167	.....	.113	.021	.83	.00	.....	.....	17.06	3.17	....	5.81	4.83	26.48	.00	5.01	1.62	1.20	....	65.18	108.85	98.00	163.66
Refined water-gas tar.....	Foundation	300	667	.046	.....	.....	.....	.....	.025	6.95	.....	3.17	5.61	.....	3.83	.....	.....	3.09	1.30	....	4.28	24.40	162.75	....	....
......do........................	Wearing surface ..	130	231	.....	.119	.021	.88	.55	.....	.....	17.97	3.17	....	10.01	3.83	17.29	1.17	5.01	1.62	2.77	....	62.84	145.16	93.37	215.70
......do........................	do	170	302	.....	.119	[1] .017	.88	[1] .13	.....	.....	17.97	2.57	....	7.04	4.38	19.76	.00	5.01	1.62	1.96	....	60.34	182.23	90.87	274.44
Oil-asphalt....................	Foundation	296	658	.046	.....	.....	.....	.....	.025	6.95	.....	3.17	5.61	.....	.....	.....	.....	3.09	1.30	....	4.28	24.40	160.55	102.78	
......do........................	Wearing surface ..	296	526	.....	.132	.021	.98	.55	.....	.....	19.93	3.17	....	15.30	3.43	18.42	1.47	5.01	1.62	3.91	....	72.26	380.09		540.64

[1] Mixed for surface binder.

The experience in bituminous macadam road construction in R. I. in 1909 by the mixing method shows the following cost data: average cost of the macadam road without binder 54.1c. per square yard; for extra bituminous construction, materials and labor about 37c. per square yard, giving an average cost of about 91c. per square yard for the completed road. The cost for mixing by hand varied from 4c. to 6c., and the cost for applying the flush coat varied from one to one and one-half cents per square yard. The amount of bituminous material used per square yard was on an average of two and one-half gallons.

It may be said in general that the cost of using a bituminous binder on a macadam road is, in the case of the penetration method about 25c. and in the case of the mixing method about 35c. over and above the cost of ordinary macadam construction.

One of the most successful moves made in the past few years for the laying of dust and the maintenance of the road surface is that brought about through the use of bituminous binders with the local materials such as sand gravel and earth. Roads made of such mixtures have given splendid service and the continuance of this custom means the growth of many of our suburban districts. The cost for thus treating a road is much less than the cost for the construction of a bituminous macadam and under the light traffic the results would be in many ways equally as satisfactory. In Massachusetts where a large amount of road has been built of this nature, a good grade asphaltic oil is used with a sandy gravel. Two layers of one-half gallon per square yard each are used and sand to a thickness of one inch is rolled into each layer. The cost per mile for a width of 15 feet varies from $1,800 to $2,000.

It is very difficult to say which of the processes of using the bituminous binder, by the mixing or by the penetration methods is the better. Both of the processes have their ardent adherents. In this question, as in all similar questions, circumstances must be taken into account. It seems to be the general opinion of engineers, at the present time, however, that uniformly better results are obtained by the mixing process than by the penetration process, provided the stone and binder are properly handled, but that the mixing method is too expensive unless machinery of suitable character can be employed in the mixing. When the binder is applied to the road in the penetration method better results seem to be had when this application is made from machine with liquid under considerable pressure. In the construction of the roads in Mass., where the penetration method is employed very largely with good results, a pressure of from 75 to 100 pounds per square inch on the liquid is employed.

OIL CEMENT.

The experiments with oil-cement concrete which were tried by the Office of Public Roads in a few experiments in 1909 were more extensively carried on during 1910. It is yet too early to predict the economical use of this mixture, but the results as far as they have been observed, are very favorable.

A fluid oil, either a fluid residual petroleum of a cut-back petroleum residue, has been employed. Such oils have been added to a cement mortar to an amount equal from 10 to 20% of the weight of the cement used. In the experiments in Washington, D. C., the cement thus prepared was applied to a foundation which was constructed in two courses of from one-half inch to one and one-half inches broken stone placed to a depth of five inches loose upon the prepared sub-grade, and which after rolling had received screenings from one-half inch in diameter to dust, and had been finished as in ordinary macadam road work. The thickness of the oil cement concrete used was equal to about an inch and a half to two inches which was either placed upon the foundation and then covered wth about two and one-half inches of broken stone and rolled until the voids in the broken stone were entirely filled with the oil cement concrete, or else the broken stone was first added and mixed with the oil concrete and then applied to the road and tamped until the voids were filled. In the seven experiments conducted varying amounts of oil cement stone and sand were used so as to discover if possible the best percentage of each. The cost data of these experiments which follows shows a range of from $1.15 to $1.25 per square yard for the total cost.

Table showing materials and cost data of experiments with oil-cement-concrete at Washington, D. C., 1910.

Section No.	Description.			Quantity of materials.					Cost data (cents per square yard).							Total cost—	
	Oil.	Length of section (feet).	Area of section (square yards).	Stone (cubic yards per square yard).	Screenings (cubic yards per square yard).	Sand (cubic yards per square yard).	Cement (cubic yds. per square yard).	Oil (gallons per square yard).	Stone at mixer.	Screenings at mixer.	Sand at mixer.	Cement at mixer.	Oil at mixer.	Mixing and laying concrete.	Foundation and miscellaneous.	Cents (per square yard).	Entire section.
7	**Fluid residual petroleum**	65.8	142.6	0.063	....	0.037	0.015	0.534	15.75	....	6.75	14.18	4.01	24.20	52.52	117.41	$167.43
6	...... **do**	24.3	52.6	.047	....	.024	.018	.640	11.75	....	6.00	17.01	4.80	23.05	52.52	115.13	60.56
5	...... **do**	45.0	97.5	.047	0.036	....	.018	.640	11.75	9.00	....	17.01	4.80	23.05	52.52	118.13	115.18
4	...... **do**	37.0	80.2	.047	.024	.012	.018	.960	11.75	6.00	3.00	17.01	7.20	23.05	52.52	120.53	96.67
3	**Cut-back pertoleum** residue	68.0	147.3	.047	.024	.012	.018	.937	11.75	6.00	3.00	17.01	12.18	23.05	52.52	125.51	184.88
2	...... **do**	72.4	156.9	.047	.024	.012	.018	.625	11.75	6.00	3.00	17.01	8.13	23.05	52.52	121.46	190.57
1	**None**	39.4	85.4	.047	.024	.012	.018	....	11.75	6.00	3.00	17.01	....	23.05	52.52	113.33	96.78

THE COST DATA FOR OTHER EXPERIMENTS CONDUCTED IN NEW YORK CITY DURING 1910 BY THE OFFICE OF PUBLIC ROADS WITH THE SAME MATERIALS ARE SEEN IN THE FOLLOWING TABLE:

Table showing materials and cost data of experiments with oil-cement-concrete at New York, N. Y., 1910.

Section No.	Description.			Quantity of material.				Cost data (cents per square yard).						Total cost—	
	Oil.	Length of section (feet).	Area of section (square yards).	Stone (cubic yards per square yard).	Sand (cubic yards per square yard).	Cement (cubic yds. per square yard).	Oil (gallons per square yard).	Stone at mixer.	Sand at mixer.	Cement at mixer.	Oil at mixer.	Mixing and laying concrete.	Prepar'g foundation and miscellaneous.	Cents (per square yard).	Entire section.
1	Fluid residual petroleum	163	580	0.123	0.062	0.031	1.61	18.45	7.13	27.62	12.07	21.78	2.28	89.33	$578.11
2	do	77	274	.123	.062	.031	1.07	18.45	7.13	27.62	8.02	21.78	2.28	85.28	233.67
3	Cut-back petroleum residue	100.5	357	.123	.062	.031	1.88	18.45	7.13	27.62	24.44	21.78	2.28	101.70	363.07
4	do	103.5	368	.123	.062	.031	1.88	18.45	7.13	27.62	24.44	21.78	2.28	101.70	374.26

The total cost per square yard in the above is slightly less than the cost for the experimental roads built in Washington, D. C., the cost here being from about 85c. to $1.01.

Another experiment with oil-cement concrete was carried on at Bridgewood, N. J., in 1910. This experiment differed from the others in that the oil-cement was placed upon the other concrete layer while the lower one was still fresh and soft, thus assuring a perfect bond between the two. In this experiment the average thickness of the whole concrete layer was five and one-half inches, the upper one and one-half to two inches only containing the oil.

ROCK ASPHALT.

Another important material that has come into use quite extensively in the last few years is native rock asphalt. This material is a sandstone which has received a deposit of bituminous material through the percolation of bituminous bearing oils or gases through it in former times. The bituminous matter is found coating the grains of the sandstone and in some cases in quantity sufficient to nearly fill the voids in the stone. In general the percentage of the bituminous material does not run over 7-8% of the mass of the rock. The Kentucky rock asphalt has been considerably used for the purpose of constructing dustless roads. A test road made by the U. S. Office of Public Roads in 1907 in Bowling Green, Ky., was inspected in December, 1910, and found to be in good condition, "the cross section was well maintained; and the surface rang sharply under the blows of horses hoofs." The stone was thoroughly bonded and showed no sign of raveling. "A small specimen of the rock asphalts when dug up and warmed in the hand showed that the bitumen still had considerable life." See circulars: 89, 90, 92 and 94 of Office of Public Roads, for the particulars of this experiment.

In regard to the purchase of bituminous materials it may be said that the cost alone may have but small influence upon the suitability of the material for the particular work in hand. It should always be the rule to have the materials tested and to buy such materials only as will satisfy the tests essential for that particular class of work. The office of Public Roads has made a great many tests of materials and stands ready to advise as to the specifications necessary for different classes of work and different localities. It is hoped that the State Testing Laboratory also will soon be in shape to handle and report on bituminous binders as well as upon the other road building materials for which it is now equipped.

TABLE GIVING AMOUNT OF OIL REQUIRED FOR ONE MILE OF ROAD.

Of Various Widths and in Varying Quantities per Square Yard.

Width.	Sq Yds.	Amt. per Sq. Yd.	Gallons.
8 Feet	4693	¼ Gal.	1173
8 Feet	4693	⅓ Gal.	1564
8 Feet	4693	½ Gal.	2347
8 Feet	4693	¾ Gal.	3550
8 Feet	4693	1 Gal.	4693
8 Feet	4693	1½ Gal.	7040
10 Feet	5866	¼ Gal.	1464
10 Feet	5866	⅓ Gal.	1956
10 Feet	5866	½ Gal.	2933
10 Feet	5866	¾ Gal.	4400
10 Feet	5866	1 Gal.	5867
10 Feet	5866	1½ Gal.	8800
12 Feet	7040	¼ Gal.	1760
12 Feet	7040	⅓ Gal.	2347
12 Feet	7040	½ Gal.	3520
12 Feet	7040	¾ Gal.	5280
12 Feet	7040	1 Gal.	7040
12 Feet	7040	1½ Gal.	10560
14 Feet	8213	¼ Gal.	2053
14 Feet	8213	⅓ Gal.	2738
14 Feet	8213	½ Gal.	4107
14 Feet	8213	¾ Gal.	6160

Width.	Sq. Yds.	Amt. per Sq. Yd.	Gallons.
14 Feet	8213	1 Gal.	8213
14 Feet	8213	1½ Gal.	12310
16 Feet	9386	¼ Gal.	2347
16 Feet	9386	⅓ Gal.	3129
16 Feet	9386	½ Gal.	4693
16 Feet	9386	¾ Gal.	7040
16 Feet	9386	1 Gal.	9387
16 Feet	9386	1½ Gal.	14080
18 Feet	10560	¼ Gal.	2640
18 Feet	10560	⅓ Gal.	3520
18 Feet	10560	½ Gal.	5280
18 Feet	10560	¾ Gal.	7920
18 Feet	10560	1 Gal.	10560
18 Feet	10560	1½ Gal.	15840

From Standard Oil Co.'s Standard Road Oil Bulletin.

LOCATION OF ROADS.

By Edgar B. Kay,
Professor of Civil Engineering, University of Alabama.

The considerations governing the location of country roads are dependent upon the commercial conditions of the country to be traversed.

In well settled and long-inhabited sections the controlling element will be the character of the traffic to be accommodated. In such a section the route is generally predetermined, and there is less liberty of choice of route than in a new and sparsely settled district, where the object is to establish the easiest, shortest, and most economical line of intercommunication according to the physical character of the ground.

The determination of the best location for a road requires a study of the topographical features of the region through which the road is to pass, and also an investigation of the nature and extent of the traffic to be provided for.

Only in new and unsettled sections of country does the problem arise of locating long stretches of highway. Throughout Alabama roads already exist between all of the principal towns and villages. Many of these roads were built before the advent of railroads and form a system of intertown routes. While some of these ways were laid out with considerable engineering skill, most of them were located with no apparent regard to the topography. When the location of a road is once determined and farms and villages have been established along the way, the problem of improving such a road reduces itself to making the best grade without departing any more than possible from the old location. To relocate entirely such a road would evidently be out of the question, for it would not meet the needs of the community which it now serves. In order to meet the demands of modern traffic it will frequently be necessary to locate new highways or relocate old roads where lack of alignment or the unfavorable grades of the latter precludes the construction of an easy and fast way, such as is demanded by the motorist.

The necessity for the location of new roads will not often arise; and hence the only application of the principles of economic location will be in the re-location of comparatively short stretches of road. The original location may have been entirely satisfactory when the region was new and undeveloped, but the increase in the amount and the change in the character of the traffic may justify a very considerable change. It is probably not overstating the situation to assert that most of the principal highways in Alabama could be materially improved by careful re-location.

In locating a new road it should be remembered that the location will probably serve for many generations, and perhaps for all time, as the growing importance of the surrounding territory and the location of buildings and of division lines of the land with reference to the road make it increasingly more difficult and expensive to change the location.

"The location of a road is the field where costly errors and permanent blunders may creep in and forever fasten themselves upon the road and its users; and worst of all, these errors become more costly as the use of the road increases.

"Viewed as a question of economics, the best location is that for which the sum of the interest on the cost of construction and of the annual cost of maintaining the road and of conducting transportation over it, is a minimum."

The location of a wagon road is not however, entirely a question of economics, since the location should be made with reference to the convenience, comfort and perhaps the pleasure of those who use it; and it is frequently more of a social or political question than one of economics. It is the purpose to consider here only the economic features of location in brief form.

The principles to be observed and the methods to be employed in making the location of a wagon road are substantially the same as those used in the location of a railroad. The methods adopted in making surveys and plans for the improvement of public highways in New York State are fully described by C. W. Trumbull, Division Engineer in Bulletin No. 10 issued July, 1905, by the Department of the State Engineer and Surveyor. The method of examining the country and of making surveys will not be considered here, as such subjects fall within the province of the engineer and are elaborately presented in treatises on railroad location.

SELECTING THE ROUTE.

Byrne in his treatise on Highway Construction lays down the following principles to be observed in making final selection:

"In making the final selection the following principles should be observed as far as practicable:

(a) To follow that route which affords the easiest grades. The easiest grade for a given road will depend upon the kind of covering adopted for its surface.

(b) To connect the places by the shortest and most direct route commensurate with easy grades.

(c) To avoid all unnecessary ascents. When a road is encumbered with useless ascents, the wasteful expenditure of power is considerable.

(d) To give the center line such a position, with reference to the natural surface of the ground, that the cost of construction shall be reduced to the smallest possible amount.

(e) To cross all obstacles (where structures are necessary) as nearly as possible at right angles. The cost of skew structures increases nearly as the square of the secant of the obliquity.

(f) To cross ridges through the lowest pass which occurs.

(g) To cross either under or over railroads; for grade crossings mean danger to every user of the highway. Guards and gates frequently fail to afford protection, and the daily press is filled with accounts of accidents more or less serious; and while statistics fail to give total casualties, the aggregate must be great."

Among the more important factors that govern the location of a road, and which are applicable to either a long or short piece, are the items: distance, grades, curves, width and final alignment, which will be considered in detail.

DISTANCE.

With the terminals of a road given, the general direction is ordinarily fixed. Other things being equal, the shorter the road the better, since any unnecessary length causes a constant and threefold waste: (I) the interest on the cost of constructing the extra length; (2) the ever-recurring cost of repairing it; and (3) the time and labor employed in traveling over it. The advantage of straightness, except in perfectly flat country, is likely to be greatly overestimated. "One of the most common defects of ordinary country roads is that distance has been saved by a disregard of the desirability of easy gradients. The curving road around a hill may often be no longer than the straight one over it; for the latter is straight only with reference to the horizontal plane, but curved as to the vertical plane, while the former is curved as to the horizontal plane, but straight as to the vertical plane. Both lines curve, and the one passing over the hill is called straight only because its vertical curvature is less apparent to the eye."

Consider the case of two towns situated on the same side of a valley. A road following a direct line between them may be laid out which will gradually and equally incline from one town to the other, supposing them to be at different levels, or which will keep at the same level throughout the entire course, if the two towns be on the same level; or a line may be adopted which will gradually and equally incline from one town to the other following all the sinuosities and curves which the irregular formation of the country may render necessary for the fulfillment of these conditions. The first line would cross all the valleys and streams, necessitating deep cuttings, heavy embankments and possibly numerous bridges; the second line would avoid these expensive works by following the sinuosities of the valley. When the sides of the valley are pierced by ravines with projecting spurs and ridges intervening, instead of following the sinuosities, it will be found better to make a nearly straight line cutting through the projecting points in such a way that the material excavated will be just sufficient to fill the hollows. Now, of the above routes, the best is the straight and uniformly inclined, or the level road, although at the same time it is the most expensive. If the conditions or importance of traffic passing between the places is not sufficient to warrant so great an outlay, it will become a matter of consideration whether the course of the road should be kept straight, its surface being made to undulate with the natural face of the country; or whether a level or equally inclined line being adopted, the course of the road should be made to deviate from the direct line and follow the winding course which such a condition is supposed to necessitate.

If the two towns were situated on opposite sides of a main valley, the case would afford the same choice of a perfectly straight line with uniform grade or a winding route with practically uniform grade; the former would probably be very expensive while the latter might be very much longer.

A third condition is afforded where two towns are located in different valleys, separated by an intervening ridge more or less elevated. In this case, there is also the alternative of carrying the road across the intervening ridge in a perfectly straight line, or deviating to the right or left, and crossing the ridge at a point where the elevation is less. The proper determination of the question which of these courses is the best under the circumstances involves a consideration of the values and comparative advantages and disadvantages of inclines and curves, which will be considered later.

VALUE OF SAVING DISTANCE.

The value of a difference in length may be computed by determining (1) the amount of traffic passing over the given road, (2) the cost per ton-mile, and (3) the total cost of conducting the traffic; "and then assuming that the value of any difference of length is to the total cost of transportation as the difference of length is to the total length. If the annual cost of conducting transportation over a given road is known, then this cost divided by the length of the road gives the annual interest upon the sum that may be reasonably expended in shortening the road one mile, i. e., the value of a saving of a mile of distance; and of course dividing this sum by the number of feet in a mile will give the value of saving one foot of distance."

In Circular No. 19 published under date of April 4, 1896, by the Road Inquiry Office of the United States Department of Agriculture, the cost of wagon transportation in Alabama is given at $0.25 per ton mile; average cost per ton, $3.13; average load, 1,383 pounds; average haul in miles, 12.77. The above statistics were based upon replies received by the Department of Agriculture from only 23 counties in the State, and the price fixed, i. e., 25 cents per ton mile cannot be regarded as reliable. It is practically impossible to determine the amount of traffic on our wagon roads with any considerable degree of accuracy from existing records. Any estimate as to the value of a saving of distance, except cost of construction which can be accurately determined, is necessarily only a rough approximation and should be used only as a guide to the judgment.

GRADES.

The grade of a road is expressed in the number of feet of rise in one hundred feet of horizontal distance. A road with one foot rise in one hundred feet of length is said to have a grade of one per cent; a road of two feet rise a grade of two per cent, etc.

While a level road is the most desirable it can seldom be obtained. The problem therefore reduces itself to securing as nearly as practicable a level road and to investigating the effect of grades upon the cost of constructing and operating the road, and also to determine the limiting gradients.

Perhaps the greatest improvement that can be made in a road is to lessen the grades. This may be accomplished (1) by going around the hill or by zigzagging up the slope, or (2) by cutting down the hill. If the slope to be ascended is a long one, the first method must be employed; but if the grade is short, the second is usually cheaper. Increasing the length adds to the cost of construction and of transportation, while cutting down the hill adds only to the cost of construction. The maintenance of the longer and flatter line may cost either more or less than the shorter and steeper one according to the circumstances in the case. In a broken or rough country, a proper adjustment of the grades is the most important part of the art and science of road building; and the better the road surface the more necessary is such an adjustment."

"All grades are objectionable for two distinct reasons, viz: Because a grade increases the amount of power required to move a load up it, and because a grade may be so steep as to limit the amount of the load that can be moved over the road. The first applies to all grades whatever their rate or height; while the latter applies only to the steepest grade on the road, and in a measure is independent of its height and depends only on its rate."

Power of a Horse.

(From Bakers' Roads and Pavements.)

"The horizontal pull which a horse can exert depends upon its weight, its form or build, the method of hitching, the foothold afforded by the surface, the speed, the length of duration of the effort, the rest time between efforts, and the tax upon the future efficiency of the horse. The chief of these are the weight, the speed, and the length of the effort. With reasonably good footing a horse can exert a pull equal to one-tenth of his weight at a speed of 2 1-4 miles an hour (3 2-3 feet per second) for ten hours per day of six days per week and keep in condition. This is a common rate of exertion by farm horses in pulling plows, mowers, and other agricultural implements. Most horses can exert a tractive power equal to one-half their weight, at a slow walk about one hundred feet. On the road in emergencies, as in starting the load or in overcoming obstacles, a horse may be expected to exert a pull equal to half his weight, but at this rate he would develop a day's energy in about two hours; and consequently if he is expected to work all day, he should not be called upon to exert his maximum power except for a short time. Similarly, a horse can exert a draft equal to one-quarter of his weight for a longer time. The working tractive power of a horse may be taken as one-tenth of his weight, with an ordinary maximum of one-quarter, and in great emergencies a maximum of one-half his weight."

The following table compiled from Bulletin No. 52 of the Missouri Agricultural Experiment Station gives data of very practical experiments on the amount of pull exerted in drawing a load of constant weight over various kinds and conditions of roads and fields. In the experiments they used the same load upon two different sets of wheels: standard size with 44 inch front and 55 inch rear wheels, and the low size with 24 inch front wheels and 28 inch rear wheels. The wheels were of steel construction with six inch tires, and the difference in weight was such that the total weight of wagon and load with the high wheels was 3,762 pounds and with low wheels 3,362 pounds.

TABLE.

Kind of Road.	Condition of Road.	Number of pounds pull.	
		High Wheels.	Low Wheels.
Gravel road	Level, dry, with one inch of sand and some loose gravel	158.9	185.3
Macadam street	Clean and in fair condition	108.0	117.4
Cinder track	Dry and not firm	113.1	120.0
Dirt road	Frozen solid, one-half inch sticky mud on top	189.2	233.8
Timothy and blue-grass sod	Dry and hard, in good condition	130.0	132.0
	Dry and firm, level	248.1	300.6
Corn stubble	Dry, with small ridges	335.7	445.6
Plowed ground	Freshly plowed and dry	475.0	628.0

"This table gives the pull necessary to draw the wagon and a net load of two thousand pounds over the surfaces named. If the pull be taken as one-tenth the weight of the team, according to the above quotation from Baker, to pull the loads used in these experiments on gravel roads would require a team weighing 1,589 pounds with the standard wheels and 1,853 pounds with the low wheels.

On macadam the team would only need to weigh 1,080 pounds. On the plowed ground, however, with standard wheels it would take a team weighing 4,750 pounds to pull this load with the ordinary effort which should be required of a horse. Even supposing the team were to exert for a short distance a pull equal to one-quarter of its weight, it would need to weigh 1,900 pounds. The results in the above table were obtained from experiments conducted on level ground. If it were desired to pull these loads up grade the pull would, of course be much greater."

According to Baker, if a horse can pull 1000 pounds on a muddy level road it can pull

2000 pounds in spongy earth roads,
3000 pounds on best earth roads,
6000 pounds on macadam roads,
10,000 pounds on asphalt,
20,000 pounds on iron rails.

The following Table, arranged from Baker, gives the percentage of the load for level ground which a horse can pull up grades of different degrees of steepness.

Table showing load which a horse can draw on a grade in terms of percentage of the load on the level, when exerting a uniform force equal to one-tenth of its weight.

Rate of grade per cent.	Iron rails	Sheet Asphalt.	Broken stone.	Earth Road.		
				Best.	Spongy.	Muddy.
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
0	100	100	100	100	100	100
1	30	45	56	62	75	91
2	16	27	36	50	57	67
3	10	18	25	37	44	54
4	7	12	17	27	33	43
5	4	8	12	20	25	33
6	3	6	8	14	18	25
7	2	4	6	10	12	18
8	1	2	4	6	8	11
9	1	1	2	3	4	5

From this table appears the important fact that the smoother and harder the road is the more gentle the grades must be. On a muddy road for instance, a horse can draw 91% on a one per cent. road of what he can draw on a level road of the same kind. On the best earth road he can draw 62% and on macadam on 56%. This is due to the fact that the greatest part of the effort in drawing a load over a muddy road is consumed in squeezing the mud out from under the wheels in order to secure a solid bottom for the wheel to roll upon. The resistance which a load offers to being drawn is divided into (1) rolling resistance, which is that just above mentioned, and is due to the striking of the wheel in the surface of the road, causing the load to be continually drawn up an incline; (2) axle friction; (3) resistance of the air. These last two elements are but a very small part of the resistance to overcome on a muddy road, and the rolling resistance is nearly all of it. It follows that the added draft in pulling a load up a slight incline in a muddy road is not so great in proportion to the draft on a level stretch as it is on a hard surfaced road. On a macadam surface the rolling resistance is decreased very decidedly and the other factors make up a proportionally larger amount.

"A road is only as good as its poorest part. If a team is able to haul three tons on the level part of the road and only one ton up a certain grade at the end, the load is limited to one ton. Consequently, as far as heavy hauling is concerned, the expense necessary to put the level part in shape so that more than three tons could be hauled is of no use until the hill is put in shape so that the three tons can be hauled over that also. It is poor economy, therefore, to build a level portion of a road in good shape without making the grade such that the load hauled on the level can be pulled up the hills with the extra effort which a team is capable of exerting for a short space of time." It is therefore evident that the maximum grade that should be permitted in the location of a road must depend upon the nature of the surface the road is to have.

A better appreciation of the resistance to hauling caused by grades can be gained from the following tables taken from Byrne's Highway Construction. The percentages vary slightly from those quoted from Baker's Roads and Pavements but cover a somewhat larger range.

"The first table shows a comparison of the amount that can be hauled over different grades and the amount which it is possible to haul under similar conditions over a level road. It is seen in case of an earth road that .41 as much can be hauled on a grade of 5 per cent. (5 feet per 100) as on a level earth road and but 10 per cent. as much on a grade of 15 feet per 100. Thus if a horse can pull 1,000 pounds on a level dirt road, on a 5-foot grade he can only pull 410 pounds and on a 15 per cent. grade but 100 pounds.

Table showing the relation between Load, Grade and Surface.

Grade.	Earth.	Broken Stones.	Stone Blocks.	Asphalt.
Level	1.00	1.00	1.00	1.00
1 : 100	.80	.66	.72	.41
2 : 100	.66	.50	.55	.25
3 : 100	.55	.40	.44	.18
4 : 100	.47	.33	.36	.13
5 : 100	.41	.29	.30	.10
10 : 100	.26	.16	.14	.04
15 : 100	.10	.05	.07	---
20 : 100	.04	---	.03	---

The second Table shows the equivalent length of level road over which the same amount of energy will be expended to haul a given load as would be required on one mile of road of different grades. Thus for example, the energy required to haul a given load one mile on a grade of one foot to the 100 feet is the same as is required to haul the same load over 1 1-2 miles of level road, the surface conditions being the same; while for a grade of 10 per cent. there is required to pull one mile on this grade energy equivalent to that spent in pulling over nearly six miles of level road.

Table showing relation between length of haul and grade.

Rate of grade ft. per 100 feet.	Equivalent length of level road miles.	Rate of grade per 100 feet.	Equivalent length of level road miles.
0.0	1.000	2.50	2.244
0.25	1.121	2.75	2.363
0.50	1.242	3.00	2.484
0.75	1.373	4.00	2.982
1.0	1.500	5.00	3.444
1.25	1.622	6	3.986
1.50	1.746	7	4.844
1.75	1.871	8	4.982
2	2.000	9	5.480
2.25	2.120	10	5.977

"If properly graded, it is no exaggeration to say that one-third of the roads now frequently rendered impassable from washouts would be nearly free from the effects of such accidents. The wear to a road-bed increases approximately as the sixth power of the velocity of the storm water flowing down it, and the velocity depends primarily upon the grade. It is useless to hope to maintain a road on a steep grade under ordinary circumstances. Every year special appropriations are made to meet such emergencies. "While it cannot be said that there would be no damage to a road from storm-water even if it were properly graded, it is a fact that the amount of damage in a particular instance would have been much greater if the grades had not been reduced."

The maximum grades established in different countries and states are of interest in this connection:

"In France the standard is; on national roads, not exceeding 3 per cent; department roads, not exceeding 4 per cent; and subordinate roads, not exceeding 6 per cent. On the great Alpine road over the Simplon Pass, built under the direction of Napoleon Bonaparte, the grades average 1 in 22 (4 1-2%) on the Italian side and 1 in 17 (5.9%) on the Swiss side, and in only one place become as steep as 1 in 13 (7.7%)."

In Great Britain, the celebrated Holyhead Road, built by Telford through the very mountainous district of North Wales, has an ordinary maximum of 1 in 30 (3 1-3%) with one piece of 1 in 22 (4 1-4%) and a few short pieces of 1 in 17, on both of which pieces special care was taken to make the surface harder and smoother than on the remainder of the road."

New York maximum grade is 5 or 6%.

New Jersey maximum grade is 6%.

Michigan maximum grade is 6%.

"It will readily appear that the proper location of many factors must be taken. When such a thing is contemplated the services of the most practical highway engineer obtainable should be secured without fail." Fortunately Alabama has recently authorized the organization of a Highway Commission and the appointment of a State Highway Engineer has provided the means by which any community in the State can secure such expert service at very low cost.

RISE AND FALL.

Rise and fall is considered to be the rise in feet on an ascending grade and the corresponding feet of fall on some descending grade. One foot of rise and fall is a foot of ascent with its corresponding foot of descent. Rise and fall is measured by the number of vertical feet of rise, as shown by the differences of elevation on the profile. The introduction of rise and fall is a question between the increased cost of operation and the increased cost of construction required to fill up the hollow or cut down the hill, or between the cost of operation of the rise and fall and of the increased distance necessary to go around the obstruction. In discussing the effect of rise and fall upon the operation of a road a distinction must be made between three classes of rise and fall as follows: (See Baker on Roads) Class A. Rise and Fall on grades at a less slope than the angle of repose (the grade on which a vehicle by its own weight will maintain a uniform speed), and so situated as not to require any addition to the total power required to move a load over the road.

Class B. Rise and Fall on grades so steep as to require either the holding back of the load by the team or the application of brakes.

Class C. Rise and Fall on the maximum grades.

Take as an example of Class A Rise and Fall a road on which the grade changes from level to a descending grade of one per cent. for 400 feet in distance and then ascends by the same amount of per cent. grade until the same level is reached. The rise and fall in this case is 4 feet. The team is relieved on the down grade an amount exactly equal to the extra tax upon the up grade, and the only effect upon the team is that the effort is concentrated on the up grade instead of being uniformly distributed over the road, but as the slope is assumed to be equal to or less than the angle of repose, the maximum effort is equal to or less than twice the normal. If the grade line rises above the level instead of dipping below it, the case is not changed except that the rise is a little more unfavorable, since the team has no relief before the increase in effort is required. Therefore this class of rise and fall costs little or nothing. A change of velocity would alter the power required at any particular instant.

"If the grade is greater than the angle of repose, the team in descending must hold back the load, which is lost energy, or brakes must be applied, which tend to destroy the road; and in ascending the demand upon the team is greater than twice the normal. Therefore in either case, this class of rise and fall adds to the cost of operation.

"If the grade is a maximum, it may be sufficient to limit the amount of the load a team may draw over the level portions of the road, and therefore greatly add to the cost of transportation."

DISTANCE VS. RISE AND FALL.

In locating a road the question may arise between the relative desirability of introducing rise and fall and of increasing the length of the line. The problem then is to determine the relative value of distance and of rise and fall. If Baker's conclusion is correct, that the cost of Class A. rise and fall is not appreciable, then the distance should not be increased at all to eliminate Class A rise and Fall.

"For Class B rise and fall an approximate solution can be obtained by assuming that it costs the same to develop a certain amount of energy in overcoming Class B rise and fall as to develop a like amount of energy in moving a load on a level road. This assumption is probably reasonably correct. For example, the tractive resistance of the best broken stone road is 33 pounds per ton, and the work necessary to raise 1 ton through 1 foot of rise is 2,000 foot-pounds; therefore to develop 2,000 foot-pounds of work on a level broken stone road, a ton must be moved 2,000 divided by 33 equal to 60 feet. Hence the cost of operating 60 feet of distance on this road may be considered as equivalent to 1 foot of rise and fall of Class B. Therefore to eliminate a foot of rise and fall of Class B, the length of the road may be increased 60 feet."

The following table gives the corresponding distance for other road surfaces.

Table showing horizontal distance equivalent to 1 foot of Class B Rise and Fall.

Earth roads, muddy	Tractive resistance	200 lb. per ton	10 ft.
Earth roads, ordinary	Tractive resistance	100 lb. per ton	20 ft.
Earth roads, dry and hard	Tractive resistance	80 lb. per ton	25 ft.
Stone-block pavm't best	Tractive resistance	40 lb. per ton	50 ft.
Stone-block pavm't ordin'y	Tractive resistance	80 lb. per ton	25 ft.
Gravel, best	Tractive resistance	50 lb. per ton	40 ft.
Gravel, ordinary	Tractive resistance	80 lb. per ton	25 ft.
Broken stone road, best	Tractive resistance	33 lb. per ton	60 ft.
Broken stone road, ordin'y	Tractive resistance	50 lb. per ton	40 ft.
Sheet asphalt	Tractive resistance	20 lb. per ton	100 ft.

CURVES.

Theoretically the shortest radius of curvature allowable on roads depends upon the width of the road, and upon the maximum length of teams frequenting the road or upon the speed of the shorter teams. The length of a four-horse team and vehicle is about 50 feet and to permit such a team to keep upon a 12 foot roadway would require a radius of the inside of the curve of about 100 feet; on a 16-foot roadway a radius of about 75 feet would be required; and on a 18-foot roadway, a radius of about 66 feet. Wherever curves are necessary employ the greatest radius possible and never less than fifty feet. They may be circular or parabolic. When a curve occurs on an ascent, the grade at that point must be diminished to compensate for the additional resistance of the curve.

The width of the wheelway on curves must be increased. This increase should be one-quarter of the width for the central angles between 90 and 120 degrees, and one-half for angles between 60 and 90 degrees.

In France the minimum radius is as follows: On main and departmental roads of which the trackway is 20 to 22 feet wide, 165, and in extreme cases 100 feet; on principal country roads which are 20 feet wide, 50. In Saxony the minimum radius on principal roads is 82 feet, and on ordinary county roads it is 40 feet.

*Table showing approximately the increase in cost of hauling up different grades.

1% Grade or 1 foot in 100 feet	11%
2% Grade or 1 foot in 50 feet	23%
4½% Grade or 1 foot in 24 feet	100%
5% Grade or 1 foot in 20 feet	150%
10% Grade or 1 foot in 10 feet	400%

†Table showing approximate cost of hauling one ton per mile over different surfaces.

	cents.
Macadam dry and in good order	8
Sand-clay dry and in good order	8
Compact gravel road	13
Earth road dry and hard	18
Earth road ruts and mud	30

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*From Bul. No. 8 So. Appalachian Good Roads Assoc. Also from Farm Bulletin No. 136 U. S. Dept. Agr.

†From Bul. No. 8 Appalachian Good Roads Assoc.

DRAINAGE OF EARTH ROADS.

By Edgar B. Kay.

The drainage of roadways is of two kinds, viz: surface and subsurface. The first provides for the removal of all water falling on the surface of the roadway or which would naturally flow upon the roadway from contiguous property; the second provides for the removal of the underground waters found in the body of the ground, the thorough removal of which is of the utmost importance and essential to the life of the road surface. Drainage alone will often change a bad road to a good one, while the best stone road may be destroyed by the absence of proper drainage. "Water is the natural enemy of earth roads, for mixed with dirt it makes mud, and mud makes bad going. If water is allowed to course down the middle of the road, it will wash away the earth, and leave gullies in the surface that must be filled up by traffic or repairs. No road, however well made otherwise, can endure, if water collects or remains on it. Prompt and thorough drainage is a vital essential in all road construction especially for earth roads.

UNDERDRAINAGE.

A road-covering placed on a wet undrained bottom will be destroyed by both water and frost, and will always be troublesome and expensive to maintain. Perfect subsoil drainage is a necessity and will be found economical in the end even if it requires considerable expense to secure it.

The methods employed for securing the subsoil drainage must be varied according to the character of the natural soil, each kind of soil requiring different treatment. The natural soils may be divided into the following classes: silicious, argillaceous and calcareous; rock, swamps, and morasses.

The silicious and calcareous soils, the sandy loams and rock present no great difficulty in securing a dry and solid foundation. Ordinarily they are not retentive of water and therefore require no underdrains; ditches on each side of the road will generally prove sufficient.

The argillaceous soils and softer marls require more care; they retain water and are difficult to compact, except at the surface; and they are very unstable under the action of water and frost.

Any soil in which the standing water in the ground comes at any season of the year within 4 or 5 feet of the surface will be benefited by drainage; that is, if the soil does not have a natural subdrainage, it will be improved for road purposes by artificial subsurface drainage. It is the universal observation that roads in low places which are underdrained dry out sooner than undrained roads on high land. Underdrained roads never get as bad as do those not so drained. "Underdrainage without grading is better than grading without drainage; and in general it may be said that there is no way in which road taxes can be spent to better advantage than in subsurface drainage." Underdrainage is the very best preparation for a gravel or stone road, since gravel or stone placed upon an undrained foundation is almost sure to sink, even if slowly, whatever its thickness; whereas a thinner layer upon a drained road bed will give much better service.

While there is a quite general opinion that the sole object of underdrainage is to remove surface water it is but a small part of the advantages of the underdrainage of roads. The most important object is to lower the water level in the soil. The action of the sunshine and breeze will finally dry the surface of the road; but if the foundation is soft and spongy, the wheels will wear ruts and the horses' feet will make depressions between the ruts. The first shower fills these depressions with water, and the road is soon a mass of mud. A second object of underdrainage is to dry the ground quickly after a freeze. Under ordinary conditions in Alabama the frost action is not of sufficient occurrence or severity to justify the serious attention of the engineer or road builder except in the northern half of the State. When the frost comes out of the ground, the thawing is quite as much from the bottom as from the top. If the land is underdrained, the water when released by thawing from below will be immediately carried away. This is of the greatest importance in road drainage, since the foundation will then remain solid and the road itself will not be cut up. A third and sometimes a very important object of underdrainage is to remove what is known as the underflow. In some places where the ground is comparatively dry when it freezes in water it will be very wet when the frost comes out, similarly in certain fills in depressions the hydrostatic pressure of the water in higher contiguous lands rises slowly in the soil and if it is not drawn off by underdrainage it saturates the subsoil.

THE TILE.

The best and cheapest method of securing underdrainage is to lay a line of porous or farm tile 3 or 4 feet deep on one or both sides of the roadway. The tiles are made from terracotta or burnt clay, are porous and are far superior to all other kinds of drains. They carry off the water with greater ease, rarely if ever get choked up and only require a slight inclination to keep the water moving through them. The ordinary farm tile is entirely satisfactory for road drainage. It should be uniformly burned, straight, round in cross-section, smooth inside, and have the ends cut off square. Tile may be had from 3 to 30 inches in diameter. The smaller sizes are usually a little over one foot long,—the excess length being designed to compensate for breakage. The larger sizes are nominally 2 or 2 1-2 feet long, sometimes a little longer. Where collars are used, pieces of the larger pipe serve as collars for the smaller sizes. The collar which encircles the joint of the small tile allows a large opening, and at the same time prevents sand and silt from entering the drain. Connections should be made by proper Y-branches. Recent practice requires only that the tiles shall be laid with their ends in contact, care being taken to turn them until the ends fit reasonably close. If the bottom of the trench is made but little wider than the diameter of the tile, or if a groove is scooped out in the bottom of the trench to fit the tile, no difficulty need be apprehended from this source. The cost of tile free on board cars at factory is usually about as given in Table

Table showing cost and weight of drain tile.

Inside diameter	Price per 1,000 f. o. b. factory	Weight per foot	Number of feet in a car load.
3 inches	$ 10 00	5 lbs.	7,000
4 inches	15 00	7 lbs.	6,500
5 inches	20 00	9 lbs.	5,000
6 inches	27 00	12 lbs.	4,000
7 inches	35 00	14 lbs.	3,000
8 inches	45 00	18 lbs.	2,500
9 inches	55 00	21 lbs.	1,800
10 inches	65 00	25 lbs.	1,600
12 inches	90 00	33 lbs.	1,000
14 inches	120 00	43 lbs.	800
16 inches	150 00	50 lbs.	600
18 inches	240 00	70 lbs.	400
20 inches	300 00	83 lbs.	330
24 inches	360 00	112 lbs.	300

FALL OF DRAINS.

Ordinarily there is little danger of the grade of the tile drain being too great, and generally the problem is to secure sufficient fall. Many authorities on farm drainage and several engineering manuals assert that a fall of 2 1-2 or 3 inches per 100 feet is the lowest limit that should be attempted under the most favorable conditions; but practical experience in the northwest and western states has abundantly proved that a smaller fall will give good drainage. "In Illinois and Indiana are many lines of tile having falls of only 1-6 to 1-4 of an inch per 100 feet which are giving satisfactory drainage; and not unfrequently the ordinary porous tiles laid absolutely level directly upon the earth in the bottom of the trench, without collars or other covering over the joints, have given good drainage without trouble from the deposit of sediment."

beneath them. Tile has sometimes proved to be very effective. when laid in this manner and nearly level; but in this case it is advisable to use larger diameter pipe at the outlet and gradually decrease the diameter as the distance from the outlet increases in order to increase the fall."

Tests made at the Illinois Agricultural Experiment Station indicate that one line of tile 2 1-2 to 3 feet deep under the ditch at one side of the road will give fairly good drainage under the most adverse conditions. The above experiment consisted in the drainage of a piece of land selected as the worst that could be found in a part of the state notorious as having a large area of hard-pan which it was generally considered could not be underdrained "because the soil held water like a jug." Lines of tile were laid 2 1-2 feet deep and 50 feet apart. The water level at a point midway between the lines was lowered 18 inches, when at the same time the water level in the undrained portion of the field was only 6 inches below the surface. In this case the surface of the ground water had a slope of 1 foot in 25 feet. Baker says that other observations confirm the above result for the slope of the surface of saturation. The exact form of the surface of saturation is not known, but it is known to be a curve slightly convex upward. The inclination varies with the nature of the soil. It is most convex near the tile, and is most convex immediately after a rain and gradually thereafter approaches an inclined plane.

For agricultural drainage it is conceded that it is sufficient to place lines of tile 100 feet apart, provided they are of reasonable size and at sufficient depth. A tile will give agricultural drainage 50 feet on either side of it; that is a tile under only one side ditch will give agricultural drainage for the traveled way, since the traveled way is usually not more than 50 feet wide and on most Alabama roads much narrower. More thorough drainage is required for road purposes, because "when damp, most soils will pack, which is harmful to agricultural land and beneficial to the road." In some localities a stratum of hard pan near the surface makes it necessary to lay the tile so shallow that two lines are really required; and sometimes the tile is so small or poorly laid that one line is not sufficient. "In case of doubt as to whether one or two lines of tile are needed put in one and watch results. If both sides of the road are equally good, another tile drain is not needed." "In making these observations care should be taken not to overlook any of the factors, as for example, the difference in the effect of the sun upon the north and the south sides of the road, the effect of shade or of seepage water, the transverse slopes of the surface of the road, etc."

"With the same depth of digging, a tile under the side ditch is more effective than one under the center of the road. Further, if the tile is under the center, there is liability of the settling of the soil in the trench, which will make a depression and probably a mud hole; and if the tile becomes stopped, it is expensive to dig it up, and the doing so interferes with traffic. Finally, if the road is ever graveled or macadamized, the disadvantage of having the tile drain under the center of the road is materially increased."

SURFACE DRAINAGE.

Closely associated with the establishment of the grade of a road is that of the drainage. The Road Laws of Alabama vary in the powers given to County Road Commissioners and attention is here called to the necessity of adequate regulations in the Code in the development of the system of state highways recently inaugurated by legislative authority. Definite laws are needed to permit the drainage of water from the roads onto adjacent property; taking care that cultivated lands are not injured; to regulate the drainage of the run-off from road bed into private lands and to regulate those problems resulting from the inflow upon roadways of contiguous lands.

The storm water is frequently kept in the road-bed until some water course is crossed. The amount of water actually falling upon the roadway is often less than the amount that is collected from the neighboring slopes. Where provision is made for intercepting the water from the sides by ditches made part of the way up the slope there is less danger of the roadway itself being seriously damaged by the storm water.

No embankment of any sort should be allowed which keeps the storm water in the road-way. Wherever it is necessary to dig a ditch through adjacent lands in order to dispose of the road drainage, it may be just that damages be allowed the landowner. As a rule, however, the actual damage can be practically nothing, or at most very little, provided a little judgment is exercised in placing these lateral drains. The more frequent the outlets from the road of the storm water the less the volume which it is necessary to carry in the gutters and side ditches, and consequently, the less the amount of water and destruction of the road-bed.

The drainage of the surface of a road is of the greatest importance and is provided for by making the surface crowning and in keeping it smooth. Water upon the surface of the road can not be carried away by the underdrains, since the water can reach them only after it has penetrated and softened the road surface. The slope from the center to the side should be enough to carry the water freely and quickly to the side ditch; and if the surface is kept free from ruts and holes, less crown will suffice than if no attention is given to keeping the surface smooth. The crown should not be so great that vehicles are compelled to keep in the center, as in that case the road will be worn hollow and surface water will be retained. In extreme cases of too much crowning, it is sometimes difficult for vehicles to turn out in passing. Provided the road is properly maintained and the surface kept smooth, a crown of one inch to one foot is ample. More crown is required on very steep grades, as the water in flowing from the center of the road to the sides travels diagonally and not at right angles to the center line as in the case of level road.

If the surface is too flat the water will follow down the center, the wheel-tracks will become deepened, stones become loosened, and the road surface made rough and dangerous.

The drainage of the surface of a road is chiefly a matter of maintenance and one of the most common defects of maintenance is the failure to fill the ruts and keep the surface smooth so that the water will be promptly discharged into the side ditches. A comparatively shallow rut will nullify the effect of any reasonable amount of crown, and wear deeper and deeper with each passing vehicle.

CROSS-DRAINAGE.

"Catch-waters," "water-breaks," "hummocks" or "thank-you-marms" to turn the surface drainage into the side ditches should not be constructed on improved roads. They increase the grade and are an impediment to convenient and easy travel. Where it is necessary that water should cross the road a culvert should be built.

Whatever the form of the road surface, if the hillside is steep there should be a "catch-water" above the road to prevent the water from the hillside above from flowing down on the road. It should be at least 6 feet back from the top of the side slope or excavation and should have a width and depth according to the amount of water to be intercepted.

CULVERTS.

Culverts are necessary for carrying under a road the streams it crosses, and also for conveying the surface water collected in the side ditches from the upper side to that side on which the natural water courses lie.

Especial care is required to provide an ample way for the water to be passed. If the culvert is too small, it is liable to cause a washout, entailing interruption of traffic and cost of repairs, and possibly may cause accidents that will require the payment of large sums for damages. It is the province of the engineer to design a culvert of sufficient but not extravagant size.

The area of water-way required depends (1) upon the rate of rainfall; (2) the kind and condition of the soil; (3) the character and inclination of the surface; (4) the condition and inclination of the bed of the stream; (5) the shape of the area to be drained, and the position of the branches of the stream; (6) the form of the mouth and the inclination of the bed of the culvert; and (7) whether it is permissible to back the water up above the culvert, thereby causing it to discharge under head.

(1) It is the maximum rate of rainfall during the severest storms which is required in this connection. The Government records show a rate of rainfall per hour for a period of five minutes of 9 inches at Bismark, N. D.; a rate of 6.60 inches per hour for a period of ten minutes at Jacksonville, Fla.; and of 2.55 inches per hour for a period of an hour at Galveston, Texas. Since one inch of rainfall per acre equal 3,630 cubic feet, the Galveston record of 2.55 inches represents 9256.5 cubic feet per acre per hour. Owing to various causes, not more than 50 to 75 per cent. of this amount will reach the culvert within the same hour. The maxium run-off of any American stream of which there is record is about 157 second feet per square mile of drainage area.

(2) The amount of water to be drained off will depend upon the permeability of the surface of the ground, which will vary greatly with the kind of soil, the degree of saturation, the condition of the cultivation, the amount of vegetation, etc.

(3) The rapidity with which the water will reach the watercourse depends upon whether the surface is rough or smooth, deep or flat, barren or covered with vegetation, etc.

(4) The rapidity with which the water will reach the culvert depends upon whether there is a well-defined and unobstructed channel, or whether the water finds its way in a broad thin sheet. If the water course is unobstructed and has a considerable inclination the water may arrive at the culvert nearly as rapidly as it falls; but if the channel is obstructed, the water may be much longer in passing the culvert than in falling.

(5) The area of the water-way depends upon the amount of the area to be drained; but in many cases the shape of this area and the position of the branches of the stream are of more importance than the amount of territory. If the area is long and narrow, the water from the lower portion may pass through the culvert before that from the upper end arrives; or, on the other hand, if the upper end of the area is steeper

than the lower, the water from the former may arrive simultaneously with that from the latter. If the lower part of the area is better supplied with branches than the upper the water from the lower portion may be carried beyond the culvert before the arrival of water from the upper portion, on the other hand if the upper portion is better supplied with well defined water-courses, the water from the whole area may reach the culvert at nearly the same time. In large areas the shape of the catchment and the position of the water-courses are very important considerations.

(6) The efficiency of the culvert may be materially increased by so arranging the upper end that the water may enter it without being retarded. The discharging capacity of a culvert can also be increased by increasing the inclination of its bed, provided the channel below will allow the water to flow away freely after passing the culvert.

(7) The discharging capacity of a culvert can be greatly increased by allowing the water to dam up above it. A culvert will discharge twice as much under a head of four feet as under a head of one foot. The practice of designing culverts to discharge under head is not recommended. Many culverts of ample area fail to carry off the water properly, because of floating material, such as brush, trees, etc., which are allowed to obstruct the channel and choke up the culvert.

The determination of the values of the above different factors entering into the problem is largely a matter of experience and judgment. An estimate of any one of the factors is liable to be in error 100 per cent. or more. Mathematical exactness is ordinarily not required by the problem nor warranted by the data. The question is not one of 10 or 20 per cent. increase; for if a 2-foot pipe is insufficient, a 3-foot pipe will probably be the next size, an increase of 225 per cent; and if a 6-foot arch culvert is too small, an 8-foot will be used, an increase of 180 per cent. The real question is whether a 2-foot pipe or an 8-foot arch culvert is needed.

Valuable data on the proper size of any particular culvert may be obtained (1) by observing the existing openings on the same stream; (2) by measuring, if practicable at time of high water, a cross-section of the stream at some narrow place and the determination of the velocity of the current; (3) by determining the height of high water as indicated by drift.

Numerous empirical formulas have been proposed for the determination of the required waterway area. A purely theoretical solution is impracticable, but all of the above conditions should be considered in estimating the value of the constant to be used in a particular case in applying any empirical formula of which some are quoted below. Let a=area of waterway in square feet and A=drainage area in acres. Then by

E. T. D. Myer's formula $a = C\sqrt{A}$ in which C is a coefficient varying from 1 for flat country to 4 for mountainous country and rocky ground.

A. N. Talbot's formula, $a = C\sqrt[4]{A^3}$ For steep and rocky ground C varies from 2-3 to 1. For rolling agricultural country, subject to floods at times of melting snow, and with the length of the valley three or four times its width, C is about 2-3; and if the stream is longer in proportion to its area, decrease C. In districts not affected by accumulated snow, and where the length of the valley is several times the width, 1-5 or 1-6 or less may be used. C should be increased for steep side slopes, especially if the upper part of the valley has a much greater fall than the channel at the culvert.

J. I. Fanning's formula, $a = 0.23\sqrt[6]{A^5}$ in which no allowance is made for variations in conditions which affect the flow.

C. B. & Q. formula, $a = 0.46875\, A/(3+0.079\sqrt{A})$.

SIDE DITCHES.

The side ditches are to receive the water from the surface of the traveled way, and should carry it rapidly and entirely away from the roadside. They are useful, also, to intercept and carry off water that would otherwise flow from the side hills upon the road. Ordinarily they need not be deep; but, if possible, should have a broad, flaring side toward the traveled way, to prevent accident if a vehicle should be crowded to the extreme side of the roadway. The outside bank should be flat enough to prevent caving.

If the road is tiled as hereinbefore recommended, the side ditch need not be very large; but it should be of such form as to permit its construction with the road machine or scraping grader or in part with the drag scraper, instead of requiring it to be made by hand. On comparatively level ground, the proper form of side ditch is readily and cheaply made with the usual road machine. If a larger ditch is needed, it should be of such a form as to be made chiefly with the drag-scoop scraper. A deep narrow ditch is expensive to maintain, since it is easily obstructed by the caving banks, by weeds and by floating trash. The shallow ditch is easy and cheap to construct and also to maintain.

If it is necessary to carry water along the side of the road through a rise in the ground, it is much better to lay a line of tile and nearly fill the ditch than to attempt to maintain a narrow deep ditch. A tile is much more effective per unit of cross section than most open ditches.

The side ditch should have a uniform grade and a free outlet into some stream or water course, so as to carry the water entirely away from the road. No good can be obtained with side ditches that hold the water until it evaporates.

When the road is in excavation, great care should be taken that a ditch is provided on each side to carry away the water so that it shall not run down the middle of the road. Every road should have side ditches, even one that runs straight down the side of the hill. The steepest road needs the side ditch most, although it often has none.

If it can be prevented, no attempt should be made to carry water long distances in side ditches; for large bodies of water are hard to handle, and are liable to become very destructive. Side ditches should discharge frequently into the natural watercourses, though to compass this, it may be necessary in some cases to carry the water from the high side to the low side of the road.

THE USE OF WIDE TIRES.

By Wm. F. Prouty.

Numerous tests made under all kinds and conditions of roads show that the draft of a wagon with wide tires is, with very few exceptions, less than that of a wagon and narrow tires. The real advantage of the wide tire is not, however, so much due to the less draft as to a much more important fact. Wherever the wide tires are used on a road instead of the narrow tires there is always an improvement in the character of the road. The surface becomes much more even and harder, the deep ruts are filled and the drainage in consequence improved. The reason for this betterment is evident. It is merely that the weight of the load is distributed over a much larger area of tire and in consequence there is a much less cutting and grinding force, with an attendant less rutting and powdering of the road material.

The wide tire is most effective on heavy wagons and in the country districts where the roads are both narrow and made of soft materials. Here there is a tendency for the wheels to run in the same narrow tracks and consequently for ruts to be formed.

The beneficial effects of the wide tire are not, however, confined to the country districts and the dirt road. On the macadam road, where the surface is hard, the narrow tire naturally has less cutting effect than on sand and clay. Its deleterious effects are, however, readily seen. Many stones are loosened and thrown out of place while only a small percentage of those already on the surface are imbedded again by the narrow tired wheels. The greater pressure of the narrow tires increases the amount of rock which is ground to a powder and in consequence the destruction of the road is hastened.

The action of the broad tire on the macadam road is most evidenced by the absence of coarse pieces of rock from the surface, these having been imbedded by the rolling effect of the wider tires.

On narrow roads where the running surface is restricted, a doubly beneficial effect may be obtained by using a different length axle for the front and rear wheels in connection with broad tires. I have observed the use of such on a limestone macadam road leading from the Onondaga Indian Reservation, Onondaga County, N. Y., and in other places with uniform highly satisfactory results. The difference in the length of axle should be slightly less than twice the width of the tire thus allowing for a little overlap.

I wish to quote here the statement of one of the Highway Commissioners of the State of Maine in regard to the use of wide tires in his State.

> "The heavy teaming in our town is confined mainly to the three miles of dirt road over which lime rock is hauled from the quarries to the kilns. This teaming has been done for years on 2 1-2 inch tires. The resulting repairs made necessary by the continual hauling of heavy loads on narrow tires have cost this town thousands of dollars. In order that this might be remedied we made an agreement with the lime rock haulers to furnish them with the wide tired wheels fitted to their wagon axles with the understanding that if upon fair trial the experiment should prove to be of mutual advantage the haulers should buy them of the town.
>
> Four sets of wheels with six wide tires were purchased by the board of select men. A set of these wide tires was put on one of the dray wagons and rock was hauled for the draymen for one day as an experiment.
>
> Our teamster hauled the same loads and followed in the old tracks. The road was in a very dangerous condition at this time and badly rutted, so that even light driving wagons sank to their hubs in some places. The wide tires soon filled the ruts so that the wagons with the narrow tires actually hauled more rock on the last or fourth turn that day than they did in the morning.
>
> After seeing the work of these wheels for one day, the owner of the wagon wanted the whole equipment immediately and applications for the other three sets came in

> so fast that we were unable to shift the gearing fast enough. In fact one teamster drove his team for a week without brakes in order to have the wheels sooner. Since that time the wheels have been in constant use summer and winter.
>
> At the time this is being written the same amount of rock per day is being hauled in three turns that was formerly hauled in four turns by the same teams, and the drivers claim the work is being done easier by the horses. The sand stretch which was the hardest place with the narrow tires is now crossed easily.
>
> Our expenditures for repairs upon this road since the use of wide tires have become general and have amounted to almost nothing. By their use the ruts are filled up and the road-bed is kept smooth and consequently dry."

A number of states have taken up the matter of wide tire legislation and some are compelling their citizens to use wide tires on heavily loaded wagons.

The introduction of wide tires may be brought about in several ways. Chief among these methods the following are probably the most feasible: by prohibiting the manufacture of narrow tired wagons for heavy loads; by placing a prohibitive tax on narrow tires; by limiting the amount of load that may be hauled by the width of the tire. Of these methods the last has probably been adopted more generally than any other.

In the state of Ohio the following is considered the logical arrangement of burdens for varying width of tires where there is a 3,400 pound limit for tires of less than three inches in width:

Vehicles with 1 inch tires	900 pounds.
Vehicles with 1 1-2 inch tires	1200 pounds.
Vehicles with 1 3-4 inch tires	1600 pounds.
Vehicles with 2 inch tires	2000 pounds.
Vehicles with 2 1-4 inch tires	2400 pounds.
Vehicles with 2 1-2 inch tires	2900 pounds.
Vehicles with 2 3-4 inch tires	3400 pounds.
Vehicles with 3 inch tires	4300 pounds.
Vehicles with 3 1-2 inch tires	5300 pounds.

Vehicles with 4 inch tires------------6500 pounds.
Vehicles with 4 1-2 inch tires--------7900 pounds.
Vehicles with 5 inch tires------------9500 pounds.
Vehicles with 6 inch tires----------11500 pounds.

In Ohio also various counties have adopted laws governing the use of wide tires differing more or less in their requirements of width of tire for a given load.

In Van Wert Co. for example the following regulations have been made. "It is unlawful to haul during late fall, winter and spring, except when roads are dry and frozen, a burden of

3400 pounds on less than 3 inch tire.
3500 pounds on less than 4 inch tire.
3600 pounds on less than 6 inch tire.
4000 pounds on less than 8 inch tire.
8 inch or more may carry 6000 pounds.

These weights are inclusive of vehicles. Trustees, road superintendents and road commissioners are to enforce the law."

In practically all cases the counties in Ohio have passed laws requiring wider tires, for the heavier loads, than is shown in the table of logically arranged burdens.

It would seem that such law should be operative especially during all times when the road is in a condition to be rutted easily.

In all places where the wide tire laws have been in operation there has been marked improvement in the character of the roads. In many places where rough roads have been gone over in the drier season by many wide tired wagons, especially if the front and back axles are of different length, the roads have been wonderfully improved. Under the same conditions with narrow tired wagons, there would have been developed ruts of considerable depth.

APPENDIX

*LIST OF BOOKS BEARING ON ROAD AND STREET CONSTRUCTION.

	Name.	*Author.*	*Price.*
a	American Highways	Shaler	$1.50
	Asphalts	Boorman	3.00
	Catalogue of Minerals	Prof. Chester	1.25
b	Cements, Limes and Plasters	Eckel	6.00
c	Cements, Mortars and Concretes	Falk	3.50
d	City Roads and Pavements	Judson	2.00
b	Civil Engineer's Pocket Book	Trautwine	5.00
e	Clays: Their Occurrence, Preperties and Uses	Ries	5.00
c	Concrete Bridges and Culverts	Tyrrell	3.00
	Concrete in Highway Construction	Atlas Cement Co.	1.00
b	Concrete, Plain and Reinforced	Trautwine, Jr.	2.00
c	Cost Data	Gillette	5.00
d	Design of Highway Bridges	Ketchum	4.00
d	Economics of Road Construction	Gillette	1.00
f	Engineering Works in Towns and Small Cities	McCullough	3.00
g	General Specifications for Concrete Bridges (2nd Ed.)	Watson	1.00
b	Highway Construction	Byrne	5.00
	Highway Engineering	Morrison	2.50
b	Hydraulic Cement	Spalding	2.00
b	Inspection of the Materials and Workmanship employed in Construction	Byrne	3.00
h	Law of Contracts	Wait	3.00
	Materials of Construction	Johnson	6.00
b	Modern Asphalt Pavement	Richardson	3.00
b	Modern Methods of Street Cleaning	Soper	3.00
e	Municipal Franchises (Vol. I)	Wilcox	5.00
	Municipal Improvements	Goodhue	1.50
e	Municipal Public Works	Whinery	1.50
i	Reinforced Concrete	Marsh	7.00
d	Roadmaking, The Art of	Frost	3.00
b	Roads and Pavements	Baker	5.00
d	Road Preservation and Dust Prevention	Judson	1.50
	Rocks and Rock Minerals	Pirsson	2.50
c	Rock Excavation, Methods and Cost	Gillette	3.00
	Rocks and Soils	Stockbridge	2.50

c	Solid Bitumens	Peckham	5.00
	Street Pavements and Paving Materials	Tillson	4.00
e	Specifications for Street Roadway Pavements	Whinery	.50
b	Symmetrical Masonry Arches	Howe	2.50
b	Text Book on Roads and Pavements	Spalding	2.00
c	Theory and Design of Reinforced Concrete Arches	Reuterdahl	2.00
	Tables for Calculating the Cubic Contents of Excavations and Embankments	Hudson	1.00
j	Roads, Their Construction and Maintenance	Allan Greenwell	1.60
	Practical Treatise on Roads, Streets and Pavements	Q. A. Gillmore	2.00
c	Concrete Bridges and Culverts	Grattan Tyrell	3.00
d	The Art of Roadmaking	Harwood Frost	3.00
	Report of the Association for Standardizing Paving Specifications, address John B. Hittell, Sec.-Treas., 5917 Winthrop Ave., Chicago		5.00
e	Highways and Byways of the South	Clifton Johnson	2.00

a Century Co., New York.
b John Wiley & Son, New York.
c Myron Clarke, Chicago.
d Engine'g News Pub. Co., N. Y.
e Macmillan Co., N. Y.
f Technical Book Agency, Chicago.
g J. B. Savage Co., Cleveland, O.
h Bender, Albany, N. Y.
i Van Nostrand, N. Y.
j D. Fourdrenier, London, Eng.

*These books may also be purchased through the Good Roads Pub. Co., 150 Nassau Street, N. Y.

OTHER REFERENCES TO ROAD LITERATURE.

1. The Reports of the Highway Commissioners of various states.
2. Circulars and pamphlets by the U. S. Office of Public Roads Dept. of Agr., distributed free upon request.
3. Good Roads Magazine, 150 Nasasu Street, N. Y., $1.00 per year.
4. Reports of State, National and International Good Roads Assosociation and Reports of special committees appointed to investigate road matters.
5. Articles and current news in a number of magazines and journals such as The Manufacturers Record, The Tradesman, The Engineering News, etc.

*TABLE SHOWING NUMBER OF TONS OF STONE PER MILE REQUIRED TO BUILD THE FOLLOWING DEPTHS AND WIDTHS.

For the information of intending road builders, we have compiled the following tables, which approximate the number of tons of thoroughly rolled stone necessary to construct each mile at the designated depths and widths.

The basis is 3,000 tons of loose stone or 3,500 tons of compressed stone for a road one mile long, sixteen feet wide and eight inches deep. A road eight inches deep, when finished, will have required at least ten inches of stone. It should be placed in two layers of five inches each, and each layer rolled down to four inches. Then the application of the three-quarter inch and screenings will bring the road to the prescribed depth; for other thickness the stone should be placed in proportion to the intended finished depths.

An observance of this rule will insure the contract thickness for the roadbed, and save the sometimes necessary expense of resurfacing before acceptance from the contractor.

A road	**8**	**feet wide and**	**4**	**inches deep will require**	**875**	**tons of stone per mile**
"	8	" "	6	" "	1,312½	" " "
"	8	" "	8	" "	1,750	" " "
"	8	" "	10	" "	2,187½	" " "
"	8	" "	12	" "	2,625	" " "
"	9	" "	4	" "	984⅜	" " "
"	9	" "	6	" "	1,476 9/16	" " "
"	9	" "	8	" "	1,968¾	" " "
"	9	" "	10	" "	2,460 15/16	" " "
"	9	" "	12	" "	2,953⅛	" " "
"	10	" "	4	" "	1,093¾	" " "
"	10	" "	6	" "	1,640⅝	" " "
"	10	" "	8	" "	2,187½	" " "
"	10	" "	10	" "	2,734⅜	" " "
"	10	" "	12	" "	3,281¼	" " "

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*From report of Commissioner of Public Roads, N. J.

A road	11	feet wide and	4	inches deep will require	1,203⅛	tons of stone per mile
"	11	" "	6	" "	1,804$\frac{11}{16}$	" " "
"	11	" "	8	" "	2,406¼	" " "
"	11	" "	10	" "	3,007$\frac{13}{16}$	" " "
"	11	" "	12	" "	3,609⅜	" " "
"	12	" "	4	" "	1,312½	" " "
"	12	" "	6	" "	1,968¾	" " "
"	12	" "	8	" "	2,625	" " "
"	12	" "	10	" "	3,281¼	" " "
"	12	" "	12	" "	3,937½	" " "
"	13	" "	4	" "	1,421⅞	" " "
"	13	" "	6	" "	2,132$\frac{13}{16}$	" " "
"	13	" "	8	" "	2,843¾	" " "
"	13	" "	10	" "	3,554$\frac{11}{16}$	" " "
"	13	" "	12	" "	4,265⅝	" " "
"	14	" "	4	" "	1,531¼	" " "
"	14	" "	6	" "	2,296⅞	" " "
"	14	" "	8	" "	3,062½	" " "
"	14	" "	10	" "	3,828⅛	" " "
"	14	" "	12	" "	4,593¾	" " "
"	15	" "	4	" "	1,640⅝	" " "
"	15	" "	6	" "	2,460$\frac{15}{16}$	" " "
"	15	" "	8	" "	3,281¼	" " "
"	15	" "	10	" "	4,101$\frac{9}{16}$	" " "
"	15	" "	12	" "	4,921⅞	" " "
"	16	" "	4	" "	1,750	" " "
"	16	" "	6	" "	2,625	" " "
"	16	" "	8	" "	3,500	" " "
"	16	" "	10	" "	4,375	" " "
"	16	" "	12	" "	5,250	" " "
"	17	" "	4	" "	1,859⅜	" " "
"	17	" "	6	" "	2,789$\frac{1}{16}$	" " "
"	17	" "	8	" "	3,718¾	" " "
"	17	" "	10	" "	4,648$\frac{7}{16}$	" " "
"	17	" "	12	" "	5,578⅛	" " "
"	18	" "	4	" "	1,968¾	" " "
"	18	" "	6	" "	2,953⅛	" " "
"	18	" "	8	" "	3,937½	" " "
"	18	" "	10	" "	4,921⅞	" " "
"	18	" "	12	" "	5,906¼	" " "
"	19	" "	4	" "	2,078⅛	" " "
"	19	" "	6	" "	3,117$\frac{3}{16}$	" " "
"	19	" "	8	" "	4,156¼	" " "
"	19	" "	10	" "	5,195$\frac{5}{16}$	" " "
"	19	" "	12	" "	6,234⅜	" " "

A road	20	feet wide and	4	inches deep	will require	2,187½	tons	of stone	per mile
"	20	" "	6	"	"	3,281¼	"	"	"
"	20	" "	8	"	"	4,375	"	"	"
"	20	" "	10	"	"	5,468¾	"	"	"
"	20	" "	12	"	"	6,562½	"	"	"

TABLES.

As many persons interested in the construction of stone roads are asking questions about their cost, we enclose a table to show at a glance the number of square yards at different widths in a mile of road; also the cost at different widths, and various prices per square yard. Any variations from these prices can be quickly ascertained by adding, substracting, multiplying and dividing for a less or greater width. For example, a road eight feet wide has 4,693 1-3 square yards in one mile. To obtain the number of square yards in a road having a width of nine feet, add one-eighth to the foregoing figures, and in one having a width of seven feet, subtract one-eighth; in one of twice the width given in the table, multiply by two.

SQUARE YARDS IN ONE MILE OF

8	feet in width	4,693⅓	square yards.
10	"	5,866⅔	"
12	"	7,040	"
14	"	8,213⅓	"
16	"	9,386⅔	"
18	"	10,560	"

8	feet wide, or	4,693⅓	square yards, at	25c.	per yard	$1,173 33⅓
10	"	5,866⅔	"	25c.	"	1,466 66⅔
12	"	7,040	"	25c.	"	1,760 00
14	"	8,213⅓	"	25c.	"	2,053 33⅓
16	"	9,386⅔	"	25c.	"	2,346 66⅔
18	"	10,560	"	25c.	"	2,640 00
8	"	4,693⅓	"	30c.	"	1,408 00
10	"	5,866⅔	"	30c.	"	1,760 00
12	"	7,040	"	30c.	"	2,112 00
14	"	8,213⅓	"	30c.	"	2,464 00
16	"	9,386⅔	"	30c.	"	2,816 00
18	"	10,560	"	30c.	"	3,168 00

feet wide, or	4,693⅓	square yards, at	35c.	per yard	$1,612 66⅔
"	5,866⅔	"	35c.	"	2,053 33⅓
"	7,040	"	35c.	"	2,464 00
"	8,213⅓	"	35c.	"	2,874 66⅔
"	9,386⅔	"	35c.	"	3,285 33⅓
"	10,560	"	35c.	"	3,696 00
"	4,693⅓	"	40c.	"	1,877 33⅓
"	5,866⅔	"	40c.	"	2,346 66⅔
"	7,040	"	40c.	"	2,816 00
"	8,213⅓	"	40c.	"	3,285 33⅓
"	9,386⅔	"	40c.	"	3,754 66⅔
"	10,560	"	40c.	"	4,224 00
"	4,693⅓	"	45c.	"	2,112 00
"	5,866⅔	"	45c.	"	2,640 00
"	7,040	"	45c.	"	3,168 00
"	8,213⅓	"	45c.	"	3,696 00
"	9,386⅔	"	45c.	"	4,224 00
"	10,560	"	45c.	"	4,752 00
"	4,693⅓	"	50c.	"	2,346 66⅔
"	5,866⅔	"	50c.	"	2,933 33⅓
"	7,040	"	50c.	"	3,520 00
"	8,213⅓	"	50c.	"	4,106 66⅔
"	9,386⅔	"	50c.	"	4,693 33⅓
"	10,560	"	50c.	"	5,280 00
"	4,693⅓	"	55c.	"	2,581 33⅓
"	5,866⅔	"	55c.	"	3,226 66⅔
"	7,040	"	55c.	"	3,872 00
"	8,213⅓	"	55c.	"	4,517 33⅓
"	9,386⅔	"	55c.	"	5,162 66⅔
"	10,560	"	55c.	"	5,808 00
"	4,693⅓	"	60c.	"	2,816 00
"	5,866⅔	"	60c.	"	3,520 00
"	7,040	"	60c.	"	4,224 00
"	8,213⅓	"	60c.	"	4,928 00
"	9,386⅔	"	60c.	"	5,632 00
"	10,560	"	60c.	"	6,336 00
"	4,693⅓	"	65c.	"	3,050 66⅔
"	5,866⅔	"	65c.	"	3,813 33⅓
"	7,040	"	65c.	"	4,576 00
"	8,213⅓	"	65c.	"	5,338 66⅔
"	9,386⅔	"	65c.	"	6,101 33⅓
"	10,560	"	65c.	"	6,864 00

8	feet wide, or	4,693$^{1}/_{3}$	square yards, at	70c.	per yard	$3,285 33$^{1}/_{3}$
10	"	5,866$^{2}/_{3}$	"	70c.	"	4,106 66$^{2}/_{3}$
12	"	7,040	"	70c.	"	4,928 00
14	"	8,213$^{1}/_{3}$	"	70c.	"	5,749 33$^{1}/_{3}$
16	"	9,386$^{2}/_{3}$	"	70c.	"	6,570 66$^{2}/_{3}$
18	"	10,560	"	70c.	"	7,392 00
8	"	4,693$^{1}/_{3}$	"	75c.	"	3,520 00
10	"	5,866$^{2}/_{3}$	"	75c.	"	4,400 00
12	"	7,040	"	75c.	"	5,280 00
14	"	8,213$^{1}/_{3}$	"	75c.	"	6,160 00
16	"	9,386$^{2}/_{3}$	"	75c.	"	7,040 00
18	"	10,560	"	75c.	"	7,920 00
8	"	4,693$^{1}/_{3}$	"	80c.	"	3,754 66$^{2}/_{3}$
10	"	5,866$^{2}/_{3}$	"	80c.	"	4,693 33$^{1}/_{3}$
12	"	7,040	"	80c.	"	5,632 00
14	"	8,213$^{1}/_{3}$	"	80c.	"	6,570 66$^{2}/_{3}$
16	"	9,386$^{2}/_{3}$	"	80c.	"	7,509 33$^{1}/_{3}$
18	"	10,560	"	80c.	"	8,448 00
8	"	4,693$^{1}/_{3}$	"	85c	"	3,989 33$^{1}/_{3}$
10	"	5,866$^{2}/_{3}$	"	85c.	"	4,986 66$^{2}/_{3}$
12	"	7,040	"	85c.	"	5,984 00
14	"	8,213$^{1}/_{3}$	"	85c.	"	6,981 33$^{1}/_{3}$
16	"	9,386$^{2}/_{3}$	"	85c.	"	7,978 66$^{2}/_{3}$
18	"	10,560	"	85c.	"	8,976 00
8	"	4,693$^{1}/_{3}$	"	90c.	"	4,224 00
10	"	5,866$^{2}/_{3}$	"	90c.	"	5,280 00
12	"	7,040	"	90c.	"	6,336 00
14	"	8,213$^{1}/_{3}$	"	90c.	"	7,392 00
16	"	9,386$^{2}/_{3}$	"	90c.	"	8,448 00
18	"	10,560	"	90c.	"	9,504 00
8	"	4,693$^{1}/_{3}$	"	95c.	"	4,458 66^{2}/
10	"	5,866$^{2}/_{3}$	"	95c.	"	5,573 33^{1}/
12	"	7,040	"	95c.	"	6,688 00
14	"	8,213$^{1}/_{3}$	"	95c.	"	7,802 66^{2}/
16	"	9,386$^{2}/_{3}$	"	95c.	"	8,917 33^{1}/
18	"	10,560	"	95c.	"	10,032 00
8	"	4,693$^{1}/_{3}$	"	$1.00	"	4,693 33^{1}/
10	"	5,866$^{2}/_{3}$	"	1.00	"	5,866 66^{2}/
12	"	7,040	"	1.00	"	7,040 00
14	"	8,213$^{1}/_{3}$	"	1.00	"	8,213 33^{1}/
16	"	9,386$^{2}/_{3}$	"	1.00	"	9,386 66^{2}/
18	"	10,560	"	1.00	"	10,560 00

*TABLE FOR GRAVEL.

Table showing number of cubic yards of gravel required in the construction of one mile of gravel road, of widths varying from 6 feet to 20 feet, and depths from 6 to 12 inches. The within quantities should be multiplied by 1⅓ to give the number of cubic yards of loose gravel required to make the within depths of compact gravel.

ONE MILE IN LENGTH	Number of feet in width.	Number of cubic yards in road 6 inches deep.	Number of cubic yards in road 7 inches deep.	Number of cubic yards in road 8 inches deep.	Number of cubic yards in road 9 inches deep.	Number of cubic yards in road 10 inches deep.	Number of cubic yards in road 11 inches deep.	Number of cubic yards in road 12 inches deep
One mile	6 feet wide	586 2/3	684 4/9	782 2/9	880	977 7/9	1,075 5/9	1,173 1/3
One mile	7 feet wide	684 4/9	798 14/27	912 16/27	1,026 2/3	1,140 20/27	1,254 22/27	1,368 8/9
One mile	8 feet wide	782 2/9	912 16/27	1,042 26/27	1,173 1/3	1,303 19/27	1,434 2/27	1,564 4/9
One mile	9 feet wide	880	1,026 2/3	1,173 1/3	1,320	1,466 2/3	1,613 1/3	1,760
One mile	10 feet wide	977 7/9	1,140 20/27	1,303 19/27	1,466 2/3	1,629 17/27	1,792 16/27	1,955 5/9
One mile	11 feet wide	1,075 5/9	1,254 22/27	1,434 2/27	1,613 1/3	1,792 16/27	1,971 23/27	2,151 1/9
One mile	12 feet wide	1,173 1/3	1,368 8/9	1,564 4/9	1,760	1,955 5/9	2,151 1/9	2,346 2/3
One mile	13 feet wide	1,271 1/9	1,482 26/27	1,694 22/27	1,906 2/3	2,118 14/27	2,330 10/27	2,542 2/9
One mile	14 feet wide	1,368 8/9	1,597 1/27	1,825 5/27	2,053 1/3	2,281 13/27	2,509 17/27	2,737 7/9
One mile	15 feet wide	1,466 2/3	1,711 1/9	1,955 5/9	2,200	2,444 4/9	2,688 8/9	2,933 1/3
One mile	16 feet wide	1,564 4/9	1,825 5/27	2,085 25/27	2,346 2/3	2,607 11/27	2,868 4/27	3,128 8/9
One mile	17 feet wide	1,662 2/9	1,919 7/27	2,216 8/27	2,493 1/3	2,770 10/27	3,047 11/27	3,324 4/9
One mile	18 feet wide	1,760	2,053 1/3	2,346 2/3	2,640	2,933 1/3	3,226 2/3	3,520
One mile	19 feet wide	1,857 7/9	2,167 11/27	2,477 1/27	2,786 2/3	3,096 8/27	3,405 25/27	3,715 5/9
One mile	20 feet wide	1,955 5/9	2,281 13/27	2,607 11/27	2,933 1/3	3,259 7/27	3,585 5/27	3,911 1/9

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*From report of Commissioner of Public Roads, N. J. 1907.

*TABLE OF SPECIFIC GRAVITY AND WEIGHT OF VARIOUS †SOLID ROCKS.

No. of samples tested.	Name.	Specific Gravity.			Weight per cu foot solid rock			W'ght per cubic yd. solid rock		
		Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.
3	Peridotite (trap)	3.55	3.25	3.40	221	203	212	2,984	2,741	2,862
124	Diabase (trap)	3.20	2.60	2.95	200	162	184	2,700	2,187	2,484
33	Diorite (trap)	3.35	2.70	2.85	209	168	178	2,821	2,268	2,403
60	Schist	3.20	2.65	2.90	200	165	181	2,700	2,227	2,443
11	Felsite	2.80	2.50	2.65	175	156	165	2,362	2,106	2,227
53	Quartzite	3.10	2.50	2.70	193	156	168	2,605	2,106	2,268
358	Limestone	3.10	2.00	2.65	193	125	165	2,605	1,687	2,227
106	Granite	3.00	2.00	2.65	187	125	165	2,524	1,687	2,227

*From U. S. Dept. of Agriculture, Bulletin No .388, p. 7.
†Crushed stone is about one-half as heavy, being about 50% void.

EXPERIMENTAL ROADS CONSTRUCTED BY THE OFFICE OF PUBLIC ROADS IN THE STATE OF ALABAMA. UP TO 1911.

Location.	Year.	Length.	Kind.	Cost.
Snow Hill	1906	4,461 feet	Macadam	$ 2,465.53
Uniontown	1906	5,500 feet	Macadam	2,677.06
Anniston	1907	4,141*feet	Macadam	2,889.85
Opelika	1908	950 feet	Macadam	591.50
Eufaula	1908	3,000 feet	Sand Clay	122.58
Seale	1908	2,330 feet	Sand Clay	334.28
Athens	1908	3,000†feet	Gravel	1,674.32
Birmingham	1909	about 1 m'e	Macadam‡	13,251.05
Union Springs	1909	2,200 feet	Sand Clay	183.51
Tyler-Salem	1910	4,300 feet	Sand Clay	1,628.40

*Square yards of surface.
†Excluding $82.32 cost of concrete culvert.
‡Tarred slag and macadam.

*TABLE SHOWING COMPARATIVE VALUE OF DIFFERENT PAVEMENTS.

Data for Table is average of ten replies to the inquiry sent out by the Department of Agriculture, Washington.

Pavement qualities.	Percentage.	Granite.	Sandstone.	Asphalt (sheet).	Asphalt (block).	Brick.	Macadam.	Creosoted wood.
Cheapness (first cost)	14	4.0	4.0	6.5	6.5	7.0	14.0	4.5
Durability	20	20.0	17.5	10.0	14.0	12.5	6.0	14.0
Ease of maintenance	10	9.5	10.0	7.5	8.0	8.5	4.5	9.5
Ease of cleaning	14	10.0	11.0	14.0	14.0	12.5	6.0	14.0
Low traction resistance	14	8.5	9.5	14.0	13.5	12.5	8.0	14.0
Freedom from slipperiness (average of conditions)	7	5.5	7.0	3.5	4.5	5.5	6.5	4.0
Favorableness to travel	4	2.5	3.5	4.0	3.5	3.0	3.0	3.5
Acceptability	4	2.0	2.5	3.5	3.5	2.5	2.5	4.0
Sanitary quality	13	9.0	8.5	13.0	12.0	10.5	4.5	12.5
Total number of points	100	71.0	73.5	76.0	79.5	74.5	55.0	80.0
Average cost per square yard, laid, 1905	----	$3.26	$3.50	$2.36	$2.29	$2.06	$0.99	$3.10

Favorableness to travel is dependent chiefly upon smoothness and freedom from dust and mud, secondarily upon the qualities composing "Acceptability."

Acceptability includes noise, reflection of light, radiation of heat, emission of unpleasant odors, etc. It chiefly concerns the pedestrian and the adjoining resident.

Cost per square yard includes concrete, but not excavation, curbing, etc.; except for macadam, which is not usually laid on concrete.

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*From U. S. Dept. Agr., Forest service circular No. 141, on Wood Paving in the United States.

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Finis.

GEOLOGICAL SURVEY OF ALABAMA

EUGENE ALLEN SMITH, *State Geologist*

BULLETIN No. 12

STATISTICS OF THE MINERAL PRODUCTION OF ALABAMA FOR 1910

COMPILED FROM MINERAL RESOURCES OF THE
UNITED STATES.

By
CHARLES ARTHUR ABELE

MONTGOMERY, ALA.
THE BROWN PRINTING COMPANY, PRINTERS AND BINDERS
1912

LETTER OF TRANSMITTAL.

University, Ala., March, 1912.

Hon. Emmet O'Neal,
Governor of Alabama,
Montgomery, Ala.

Sir:—I have the honor to transmit herewith the manuscript of a report on the Mineral Production of Alabama for the year 1910, with the request that it be printed as Bulletin No. 12 of the Geological Survey of Alabama.

Very Respectfully,

EUGENE A. SMITH,
State Geologist.

GEOLOGICAL CORPS.

Eugene Allen Smith, Ph. D.	State Geologist.
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Charles Arthur Abele	Clerk in charge of Statistics of Mineral Production.
James A. Anderson	Clerk in charge of Mailing List.
A. T. Donoho	Stenographer.

RIVER GAGE HEIGHT OBSERVERS.

C. J. Stowe	Jackson's Gap, Tallapoosa River.
J. E. Whitehead	Riverside, Coosa River
George Havens	Epes, Tombigbee River.
J. M. Hodge	Newton, Choctawhatchie River.
W. G. Early	Pera, Pea River
J. F. Hicks	Beck, Conecuh River

From the records of daily observations of the gage readings at these places when extended through sufficient time, the calculations of available horsepower to be obtained from the different streams is made.

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PREFACE.

The statistics of all the minerals included in the following pages have been collected in cooperation with the United States Geological Survey, and have been compiled by Mr. Abele from advance chapters of the *Mineral Resources of the United States*, a publication of the Federal Survey.

The introductory and general matter in each of these articles has either been taken without change from the U. S. advance chapters or has been rearranged or condensed from these chapters, or entirely rewritten to suit it for our present purposes. In each case credit is given to the author.

STATISTICS OF THE MINERAL PRODUCTION OF ALABAMA FOR 1910

ABRASIVES.

W. C. PHALEN.

Abrasive materials fall naturally into two classes—natural abrasives and artificial abrasives. The production of artificial abrasives has shown great increase since its beginning, less than 15 years ago, and the value of these abrasives produced in this country during the last two years has exceeded that of the natural abrasives.

Under the head of natural abrasives there are included the following materials: (1) Millstones and burrstones, (2) grindstones and pulpstones, (3) oilstones and scythestones, (4) emery, (5) abrasive garnet, (6) infusorial earth and tripoli, and (7) pumice.

PRODUCTION.

Alabama produced only a limited number of millstones in 1910.

BAUXITE.

W. C. PHALEN.

USES.

The chief uses of bauxite are (1) as raw material in the production of metallic aluminum; (2) in the manufacture of aluminum salts; (3) in the manufacture of artificial abrasives; and (4) in the manufacture of bauxite brick.

(1) The use of bauxite in the production of metallic aluminum is by far the most important of those enumerated above. A large part of the entire output of Arkansas is used in the metallic aluminum industry, and the figures of production from this State have shown phenomenal growth during recent years. A large part of the French product is also used in the manufacture of metallic aluminum.

(2) Only the purer bauxite is used in the manufacture of chemicals, such as alum, aluminum sulphate, and aluminum salts in general. Freedom from oxide of iron is essential in the material to be used in the chemical manufactures.

(3) Bauxite is used on a large scale in the manufacture of the artificial abrasive, alundum, at Niagara Falls. This abrasive is made in the electric furnace by fusing calcined bauxite. It is high in crystalline aluminum oxide, and virtually amounts to a form of artificial corundum. Its quality is under complete control, and hence it can be duplicated with ease in the various abrasive products, a factor of great importance in any successful abrasive industry. Alundum is particularly efficient in the grinding of steel.

(4) The use of bauxite in the manufacture of refractory brick has by no means reached a perfected stage, but it is understood that several manufacturers are now experimenting on processes in which it is admixed with other materials. The life of bauxite- brick linings is as yet undetermined, though it is known to exceed by far the life of silica or fireclay brick. The high cost of raw material, as well as that of its manufacture, makes the ultimate cost of bauxite brick excessive as compared with that of the other two bricks mentioned.

PRODUCTION.

Alabama showed the greatest individual gain among the States, both as to quantity and value of product.

Production of bauxite in the United States, 1889-1910, by States, in long tons.

Year.	Georgia.	Alabama.	Arkansas.	Total.	Value.
1889	728	....	....	728	$2,366
1890	1,844	....	....	1,844	6,012
1891	3,301	292	....	3,593	11,675
1892	5,110	5,408	....	10,518	34,183
1893	2,415	6,764	....	9,179	29,507
1894	2,050	9,016	....	11,066	35,818
1895	3,756	13,313	....	17,069	44,000
1896	7,313	11,051	....	18,364	47,338
1897	7,507	13,083	....	20,590	57,652
1898	....	....	....	25,149	75,437
1899	15,736	14,499	5,045	35,280	125,598
1900	19,739		3,445	23,184	89,676
1901	18,038		867	18,905	79,914
1902	22,677		4,645	27,322	120,366
1903	22,374		25,713	48,087	171,306
1904	21,913		25,748	47,661	235,704
1905	15,173		32,956	48,129	240,292
1906	25,035		50,267	75,332	368,311
1907	....		....	97,776	480,330
1908	14,464		37,703	52,167	263,968
1909	22,227		106,874	129,101	679,447
1910	33,096		115,836	148,932	716,258

Production and value of Bauxite in Alabama in 1910.

Quantity Tons	Value	% of Total U. S. prod.	% of Total U. S. Value
9517	$88,068	5.31%	6.39%

CEMENT.

EUGENE A. SMITH.

PUZZOLAN OR SLAG CEMENT.

During the past four years only one establishment in Alabama has been engaged in the manufacture of slag cement, using the material from the furnaces about Birmingham. The production is included in the returns for Portland cement and cannot be given separately.

PORTLAND CEMENT.

Alabama contains large supplies of limestone, chalk, clay and shale well adapted for Portland Cement manufacture, and widely distributed throughout the state. Coal and labor are abundant and cheap, transportation facilities are excellent, and many of the best limestone and chalk localities are situated on navigable rivers, giving ready access and cheap water transportation to Galveston, New Orleans, Mobile, Charleston, and other ports of the Gulf and Atlantic Coasts. This advantage of location will be immensely increased with the opening of the Panama Canal for cement plants located in Alabama will be more than a thousand miles nearer to the Isthmus than their nearest possible competitors.

The limestones and shales of the northern part of the state lie so close to each other, and above all so close to the great coal mines which must supply the fuel, that the establishment of Portland Cement plants near the coal mines would give to this industry in Alabama the same advantages which the proximity of the iron ore, the coal, and the stone has given to the iron industry, and which has placed our state beyond competition.

As a Portland cement mixture, ready for burning, consists approximately of 75 per cent. lime carbonate and 25 per cent. of clayey matter, the material furnishing the lime carbonate is necessarily of more economic importance than that from which the silica and alumina are derived. In consequence, a Portland cement plant is usually located in the immediate vicinity of a suitable limestone, while the clay or shale required to complete the mixture may be brought some distance.

The limestone formations in North Alabama which can supply the stone adapted for use in cement manufacture are the Trenton or Pelham limestone and the Bangor or Subcarboniferous. In close proximity to both these limestone formations are the shales of the Clinton, Subcarboniferous and Coal Measures.

At the present time there are two cement plants in North Alabama, namely the Standard Portland Cement Co., located at Leeds in Jefferson County, and the Atlantic & Gulf Portland Cement Co., located at Ragland in St. Clair County. Both of these plants make use of the hard Trenton limestone, and the Standard Cement Co., according to Burchard of the U. S. Geological Survey, uses the shale of the Clinton formation whilst the Ragland Company makes use of the shales of the Coal Measures. Up to the present time no establishment is utilizing the Bangor limestone.

In Middle Alabama the soft, chalky Cretaceous limestone of the Selma Chalk, is the material utilized by the Alabama Portland Cement Co., at Spocari, near Demopolis. The same Company makes use of residual clays overlying and derived from the weathering of the Selma Chalk. During 1910 there was no production reported from the Demopolis plant.

In Southern Alabama the St. Stephens limestone outcropping east and west across the state, furnishes excellent material for Portland Cement manufacture, using either residual clays from decomposition of the limestone, or the clays of the Grand Gulf formation which are almost everywhere in close proximity to the limestone. The Mobile Cement Co. has been for some time engaged in the building of a plant at St. Stephens, but no production has yet been reported.

List of States Producing Puzzolan Cement, and Quantity and Value of Product from 1906 to 1910.

	1906	1907	1908	1909	1910
Number of plants reporting production:					
Alabama	2	1	1	1	1
Illinois	1	1	....	....	....
Kentucky	1	1	....	....	....
Maryland	1	....	....	....	....
New Jersey	1	....	....	....	....
New York	1	1	....	....	....
Ohio	2	2	2	2	2
Pensylavnia	1	1	1	1	1
Total	10	7	4	4	4
Production in barrels	481,224	557,252	151,451	160,646	95,951
Value of production	$412,921	$443,998	$95,468	$99,453	$63,286

Production and Value of Cement (Including Puzzolan and Portland) in Alabama in 1910.

Kind	No. of Producers	Quantity Produced. Bbl.	Value	Percentage of Total U. S. Value
Portland & Puzzolan....	3	406 214	$387,600	0.56%

CLAY AND CLAY PRODUCTS.

JEFFERSON MIDDLETON AND C. A. ABELE.

Clay available for the manufacture of clay products is one of the most widely spread of our minerals. Clay miners are usually also the manufacturers of the lower-grade clays, but as the higher grades of ware are reached the rule is that fewer and fewer manufacturers are also miners, until in the highest grades of ware the rule is that the manufacturer is not the miner of the clays that he uses. The figures given in the following tables represent clay that is mined and not manufactured by the miner, but is sold as clay. The clay thus sold is small in quantity compared with that consumed and includes mainly clay used for high-grade pottery, for paper making, and for refractory products.

The total quantity of clay mined in Alabama and sold as such in 1910 was 75,082 short tons, as compared with 63,408 short tons in 1909, an increase of 11,674 tons, or 18.41 per cent. The value of the clay mined in 1910 was $38,045, a decrease from 1909 of $2,887, or 7.05 per cent. Fire-clay showed an increase of 9,345 tons, or 20.7 per cent. in quantity, and a decrease of $2,950, or 8.34 per cent. in value. Miscellaneous clay, including brick clay, in 1910, increased in quantity 2329 tons, or 12.7 per cent.; and in value $63.00 or 1.12 per cent.

Quantity and Value of Clay Produced in 1910.

Kind	Quantity Produced. Tons.	Value	Avg. Value Per Ton	Percentage of Total U. S. Value
Fire Clay	54,482	$32,395	$0.594	1.5%
Miscellaneous Clay.....	*20,600	5,650	0.274	2.53%
Total	75,082	$38,045	$0.506	1.04%

*Includes brick clay; one producer.

Comparison of 1909 *and* 1910.

Kind	1909		1910		Increase or Decrease		
	Quantity Tons.	Value	Quantity Tons.	Value	Quantity Tons.	Value	Percent (Value.)
Fire Clay	45,137	$35,345	54,482	$32,395	+ 9,345	—$2,950	—8.34%
Miscellaneous Clay	18,271	5,587	*20,600	*5,650	+ 2,329	+ 63	+1.12%
Total	63,408	$40,932	75,082	$38,045	+11,674	—$2,887	—7.05%

*Includes brick clay; one producer.

CLAY-WORKING INDUSTRIES.

The total value of the clay products in 1910 was $1,667,559, a decrease from 1909 of $32,568, or 1.9 per cent. The value of the brick and tile and fire-proof products was $1,645,313, or 98.66 per cent. of the total.

Value of Brick and Tile, and Potteries, 1906-1910.

ALABAMA.

Product.	1906	1907	1908	1909	1910
Brick:					
Common—					
Quantity	166,225,000	159,315,000	120,237,000	146,180,000	135,785,000
Value	$1,046,986	$1,004,644	$690,963	$799,693	$746,961
Average per M.	$6.30	$6.31	$5.75	$5.47	$5.50
Vitrified—					
Quantity	(*)	13,362,000	18,248,000	20,444,000	19,772,000
Value	(*)	$183,895	$244,084	$262,376	$236,516
Average per M	$11.62	$13.76	$13.38	$12.83	$11.96
Front—					
Quantity	(*)	(*)	(*)	(*)	(*)
Value	(*)	(*)	(*)	(*)	(*)
Average per M.	$11.35	$13.90	$17.89	$16.19	$15.93
Fancy ....value..	....	(*)	(*)	(*)	....
Fire ....do....	$157,147	$170,711	$122,354	$196,887	$163,672
Draintile ....do....	$2.285	(*)	$2,046	(*)	$3,773
Sewer pipe..............do....	(*)	(*)	(*)	(*)	(*)
Fireproofing ....do....	(*)	(*)	(*)	(*)	(*)
Pottery:					
Red earthenware....do....	$2.620	$7.530	$15,058	$11.886	$3,475
Stoneware and yellow and Rockingham ware. Value	$35.376	$20.215	$9,031	$24,453	$16,371
Miscellaneous value.........	$444.485	$367,414	$476,070	$404,832	$496,791
Total value	$1.688.899	$1,754.409	$1,559.606	$1,700.127	$1,667,559
Number of operating firms reporting	112	100	103	100	87
Rank of State	21	20	19	22	22

* Included in "Miscellaneous."

BRICK AND TILE.

The total number of common brick produced was 135,785 thousand, a decrease from 1909 of 10,395 thousand, or 7.11 per cent. The value was $746,961, a decrease of $52,736, or 6.59 per cent. The value of vitrified brick produced in 1910 was $236,516, a decrease from 1909 of $25,860, or 9.85 per cent. The values of common brick, vitrified brick, fire-brick, and fire-proofing decreased, while the values of front-brick, drain tile, sewer pipe, silica brick, and miscellaneous ware increased. Following is a table showing the production and values for 1910, and one showing the relation of the quantities produced and the values in 1910 to those of 1909:

Brick and Tile Productiton in 1910.

Style	Quantity M.	Value	Average Value per M.	Percentage of Total Alabama Brick & Tile	Percentage of Total U. S. Value.
Common Brick	135,785	$746,961	$5.50	45.39+%	1.35%
Drain Tile		3,773		0.23 %	0.036%
Vitrified Brick or Block.....	19,772	236,516	11.96	14.37+%	2.15%
Fire Brick	10,365	163,672	15.75	9.94+%	0.90%
Miscellaneous		*494.391		30.05 %	
Total		$1,645,313		100.00 %	1.21%

* Includes front brick, sewer pipe, fire proofing, and silica brick.

Comparison of Brick and Tile in 1909 *and* 1910.

	1909.			1910.				
	Quantity M.	Value	Average Price	Quantity M.	Value	Average Price	Increase or Decrease	Percent.
Common Brick	146,180	$799,693	$5.47	135,785	$746,961	$5.50	—$52,736	— 6.59
Vitrified Brick	20,444	262,376	12.83	19,772	236,516	11.96	— 25,860	— 9.85
Drain Tile		*			3,773			
Fire Brick	14.119	196,887	13.94	10,365	163,672	15.75	— 33,215	—16.87
Miscellaneous		†403,832			‡494,391			
Total		$1,663.788			$1,645,313		—$18,475	— 1.11

* Only one producer.

† Includes Front brick. Drain tile. Sewer pipe. Fire proofing and Silica brick.

‡ Includes Front brick. Sewer pipe. Fire proofing. and Silica brick.

POTTERIES.

Alabama produces only pottery of the commoner or coarser types, red and yellow earthenware, and even this is not produced in any quantity by the nineteen active firms in 1910, most of which produced for local trade only. There was a considerable decrease in production in 1910, the decrease amounting to $14,093, or 38.78 per cent.

Value of Pottery Products in 1910.

Kind.	Value.	Percentage of Total Alabama Potteries.	Percentag of Total U. S. Value
Red Earthen Ware	$3.475	15.62+%	0.41%
Stoneware and Yellow and Rockingham Ware	*18.771	84.38—%	0.33%
Total	$22.246	100.00 %	0.07%

* Includes miscellaneous ware.

Comparison of 1909 *and* 1910.

Kind.	1909	1910	Increase or Decrease.	Percent Decrease.
Red Earthen Ware	$11,886	$3,475	—$8,411	—70.76%
Stoneware and Yellow and Rockingham Ware	24,453	*18,771	—5,682	—23.23%
Total	$36,339	$22,246	—$14,093	—38.78%

* Includes miscellaneous ware.

COAL.

E. W. PARKER.

THE COAL FIELDS OF ALABAMA.

The Alabama coal fields form the southwestern end of the great Appalachian coal region, which extends from northern Pennsylvania to central Alabama. The coal-bearing formations narrow in Tennessee, but widen abruptly in northern Alabama and cover about 6,000 square miles in the northern half of the State. There are four distinct coal-producing basins in the State, the Coosa and the Cahaba basins and the Warrior and the Plateau fields. The first three areas mentioned derive their names from the rivers which drain them. The Plateau field includes Blount, Lookout, and Sand or Raccoon mountains.

The Coosa basin is a deep syncline forming the southeast margin of the Alabama coal fields, and extending across Shelby and St. Clair counties. It is 60 miles long by 6 miles wide and contains about 350 square miles. This basin has not been thoroughly explored and the number and extent of its coal beds are not well known, but in different parts 2 to 12 beds are reported having a thickness of 3 feet or more.

The Cahaba basin is also a syncline west of the Coosa basin, to which it is parallel and from which it is separated by a faulted anti-cline. It includes parts of St. Clair, Jefferson, Shelby, and Bibb counties. Its length is 68 miles, its average width about 6 miles, and its area 394 square miles. There are many workable beds, and the total quantity of coal in the basin is large.

The Warrior basin is separated from the Cahaba basin and Blount Mountain by Jones and Murphrees valleys. It includes all of Walker County, most of Jefferson, Tuscaloosa, and Fayette counties, and smaller parts of Blount, Cullman, Winston, and Marion counties. Its known area is estimated at 4,000 square miles. Around its western and southern margin, however, the higher rocks and coal beds pass under rocks of much later age, and have probably a considerable, and possibly a great, extent to the southwest of their visible margin.

The Warrior basin has always been the scene of the greatest mining activity and production in the State. Somewhat over one-third of the total production in the Birmingham district comes from the Pratt bed, and one-fourth comes from the Mary Lee bed. Eight or ten other beds furnish the remainder of the production.

The Plateau field embraces parts of Blount, Etowah, Dekalb, Cherokee, Marshall, and Jackson counties, and is upward of 3,000 square miles in extent. The Plateau and the Warrior fields are the southwest extension of the Cumberland plateau in Tennessee. The coal resources of the Plateau field are not well known, but they are comparatively small. There are believed to be from 4 to 6 beds that are locally workable.

From a productive point of view the most important of the coal beds in Alabama are the Pratt and the Mary Lee. These two beds, with the Blue Creek, furnish the coking coals which have made Alabama one of the important iron-making States. The Pratt bed is worked in Jefferson and Walker counties, and from it 3,931,248 short tons of coal were produced in 1909, and 4,493,451 tons in 1910. The Mary Lee also is worked in Jefferson and Walker counties, and the output from this bed amounted in 1909 to 3,276,167 short tons. In 1910 the production was 3,734,049 tons. The other beds which make important contributions to the coal production of Alabama are (1) the Blue Creek, worked in Jefferson and

Tuscaloosa counties, with a production in 1909 of 798,879 short tons, and in 1910 of 746,833 tons; (2) the Thompson, worked in Bibb and Shelby counties, whose production amounted to 678,478 short tons in 1909, and 1,330,457 tons in 1910; (3) the Black Creek, one of the most extensive beds in the State, worked in Blount, Cullman, Jefferson, Marion, Walker, and Winston counties, produced 676,908 short tons in 1909, and 766,923 tons in 1910; (4) the Brookwood, including the Milldale, worked in Tuscaloosa County, had a production in 1909 amounting to 674,661 short tons, and in 1910 to 578,453 tons; (5) the Corona, worked in Walker County, produced 514,774 short tons in 1909, and 524,046 tons in 1910; (6) the Jagger, worked in Walker County, had an output ot 507,032 short tons in 1909, and 1,183,404 tons in 1910; and (7) the American, worked in Jefferson and Walker counties, which in 1909 produced 272,717 short tons, and in 1910, 297,486 tons.

The other beds to which more or less local names have been given are the Buck (Clark, Blockton, No. 1, Woodstock), Cliff, Climax, Coal City, Black Shale (Gholson), Gould, Harkness, Helena, Howard, Jefferson, Mammoth, Maylene, Montevallo, Mount Carmel, Natural Bridge, Nickel Plate, Number One, Rutilia, Warrior, and Coke (Youngblood), with a few others. Some of these are probably duplicates, two names having been applied to the same bed, but they have not been correlated.

According to the estimates prepared by Marius R. Campbell, of the United States Geological Survey, the original coal supply of Alabama when mining began was 68,903,000,000 short tons, of which 63,513,000,000 tons were in the Warrior and Plateau fields, 2,994,000,000 tons were in the Cahaba field, and 2,396,000,000 tons in the Coosa field. From this total supply of approximately 69,000,000,000 tons there had been mined at the close of 1910, 206,153,815 tons, representing an exhaustion, including waste in mining, of 309,000,000 tons, or 0.4 per cent of the total estimated supply. A more recent estimate for the Coosa field by Wm. F. Prouty, assistant to the State geologist, is 80,921,000 tons; and by Chas. Butts, of the United States Geological Survey, for the Cahaba field, is 3,200,000,000 tons.

The production of coal in Alabama in 1910 was 7.8 per cent. of the total production up to the close of the year, and 0.02 of 1 per cent. of the estimated original supply.

PRODUCTION.

Total production in 1910, 16,111,462 short tons; spot value, $20,236, 853.

In a preliminary review of the coal-mining industry in 1910, published as a press bulletin of the U. S. Geological Survey, early in January, 1911, it was stated that Alabama's production had reached the unprecedented total of 15,000,000 short tons Complete returns from all but a few mines whose aggregate output is less than 50,000 tons show that the preliminary figures were exceeded by a million tons, the output being 16,111,462 short tons. This unusually large tonnage (the largest previous production being 14,250,454 short tons in 1907) was due primarily to the strike in Illinois and other Western States, and secondarily to low water in Ohio and Kanawha rivers, which reduced shipments from Pennsylvania and West Virginia to Mississippi River points. The demand thus created for Alabama coal made up for the dullness in the iron market. This dullness was pronounced during almost the entire year and was still decidedly noticeable at the close of the year, with promise of continuation during 1911.

Compared with 1909, when the production amounted to 13,703,450 short tons, the output in 1910 showed an increase of 2,408,012 short tons, or 17.57 per cent. The conditions in 1910 naturally resulted in an advance in prices, and the total value increased from $16,306,236 to $20,236,853, a gain of $3,930,617, or 24.10 per cent. The average price per ton in 1910 was $1.26, against $1.19 in 1909.

The coal mines of Alabama were practically free from strikes in 1910, there being only 25 men idle from that cause during the year. The average time lost by the 25 men was 50 days. The labor supply, although short in places, was, on the whole, satisfactory. In some parts of the State the car supply was reported the best in several years, but in other sections quite the reverse was reported.

The coal-mining industry of Alabama was marred during 1910 by two bad disasters which together cost the lives of 131 men. The first occurred on April 20 at the Mulga mine and cost 40 lives; the second was at the Palos mine, on May 5, and cost 91 lives. The number of fatalities in these two accidents was more than the total number of deaths from all causes in either 1908 or 1909. According to the report of the chief mine inspector of the State, the total number of fatal accidents in 1910 was 238, against 129 in 1909 and 108 in 1908. The death rate per thousand in 1910 was 10.7 and the number of tons mined for each life lost was 67,695; in 1909 the death rate was 6.4 and there were 106,228 tons mined for each life lost.

The number of men employed in the coal mines of Alabama in 1910 was 22,230, who worked an average of 249 days, chiefly of 10 hours. The average production per man was 725 short tons for the year and 2.91 tons for each working day.

The number of mining machines reported in 1910 was 317, and the quantity of machine-mined coal was 2,980,122 short tons, or 18.50 per cent. of the total. In 1909, 283 machines were used in the production of 2,203,619 tons, or 15.02 per cent of the total. There were 6,772,860 short tons of coal washed in 1910, yielding 5,971,305 tons of cleaned coal and 801,555 tons of refuse.

The statistics of coal production in Alabama in 1909 and 1910, with the distribution of the product for consumption, are shown in the following table:

Coal Production of Alabama in 1909 *and* 1910, *by counties, in short tons.*

1909.

County.	Loaded at mines for shipment.	Sold to local trade and used by employees.	Used at mines for steam and heat.	Made into coke	Total quantity.	Total value.	Average price per ton.
Bibb	1,227,614	5,736	104,501	392	1,338,243	$1,791,805	$1.34
Etowah	44,416	238	1,540	....	46,194	59,869	1.30
Jefferson	3,873,937	106,305	247,099	2,949,581	7,176,922	8,222,061	1.15
St. Clair	336,072	1,336	16,597	....	354,005	460,640	1.30
Shelby	489,190	3.746	31,989	....	524,925	838,595	1.60
Tuscaloosa	648,731	9,311	44,431	304,516	1,006,989	1,158,484	1.15
Walker	2,585,006	57.749	82,538	248,483	2,973,776	3,387,988	1.14
Winston	26,578	5.700	....	....	32,278	48,489	1.50
Other counties*..	235,401	6,451	7,806	....	249,658	337,464	1.35
Small mines	....	460	....	....	460	841	1.83
Total	9,466,945	197,032	536,501	3,502,972	13,703,450	16,306,236	1.19

* Blount, Cullman, DeKalb, Jackson, and Marion.

1910.

County	Loaded at mines for shipment.	Sold local trade & used by employees	Used at mines for steam and heat	Made into coke	Total quantity.	Total value.	Av. price per ton.	Av.No.days active	Average No. of Employes.
Bibb	1.462,720	6,961	110,883	....	1,580,564	$2,370,919	$1.50	261	2,666
Etowah	169,251	1,538	1,676	....	172,465	254,798	1.48	251	388
Jefferson	4,289.536	109,377	329,777	3,570,012	8,298,702	10,247,456	1.23	255	10,832
St. Clair	411,247	2,398	14,764	....	428,409	571,675	1.33	234	524
Shelby	450.324	3,381	34,436	....	488,141	780,887	1.60	253	847
Tuscaloosa ..	412,144	6,842	54,498	607,735	1,081,219	1,232,495	1.14	264	1,496
Walker	3,395,104	66,561	87,118	239,696	3,788,479	4,395,910	1.16	227	4,889
Winston	16,192	250	......	....	16,442	25,370	1.54	156	57
Other counties* ..	237,293	8,583	10,855	....	256,731	356,723	1.39	241	531
Small mines..	....	310	......	....	310	620	2.00	....	.....
Total ..	10,843,811	206,201	644,007	4,417,443	16,111,462	20,236,853	1.26	249	22,230

* Blount, Cullman, Dekalb, Jackson, and Marion.

In the following table is presented a statement of the production of coal, in Alabama, by counties, during the last five years, with increases and decreases in 1910 as compared with 1909:

Coal Production of Alabama, 1906-1910, by Counties, in short tons.

County.	1906	1907	1908	1909	1910	Increase (+) or decrease (—), 1910.
Bibb	1,324,656	1,297,158	1,166,548	1,338,243	1,580,564	+ 242,321
Blount	*337,848					
Cullman		336,308	181,062	186,261	235,456	+ 49,195
Etowah	133,660	205,015	8,880	46,194	172,465	+ 126,271
Jefferson	6,623,115	7,526,275	5,914,129	7,176,922	8,298,702	+ 1,121,780
St. Clair	256,227	283,806	193,434	354,006	428,409	+ 74,404
Shelby	225,087	245,087	407,547	524,925	488,141	— 36,784
Tuscaloosa	1,050,792	1,047,364	712,101	1,006,989	1,081,219	+ 74,230
Walker	3,062,518	3,254,919	2,941,836	2,973,776	3,788,479	+ 814,703
Winston	27,076	35,333	28,408	32,278	16,442	— 15,836
Other counties and small mines	66,984	19,189	50,648	63,857	21,586	— 42,272
Total	13,107,963	14,250,454	11,604,593	13,703,450	16,111,462	+ 2,408,012
Total value.	$17,514,786	$18,405,468	$14,647,891	$16,306,236	$20,236,853	+$3,930,617

*Includes production of Marion County.

So far as known, the earliest record of the existence of coal in Alabama was made in 1834. The first statement of production in the State is contained in the United States census report for 1840, in which year the production is given as 946 tons. The census report for 1850 does not mention any coal production for the State, and the next authentic record is contained in the census statistics of 1860, when Alabama is credited with an output of 10,200 short tons. The mines of Alabama were probably worked to a considerable extent during the Civil War, but there are no records of the actual production until 1870, for which year the United States census reports a production of 11,000 tons. Ten years later the production had increased to 323,972 short tons, but the development of the present great industry really began in

1881 and 1882 when attention was directed to the large iron deposits near the city of Birmingham, and thus the great "boom" of that city and vicinity was inaugurated. By 1885 the coal production of the State had increased to nearly 2.500,000 tons Then followed a period of relapse and liquidation, which lasted two years, after which business settled down to a conservative and rational basis and has since developed steadily. In 1902 the coal production of the State reached a total of over 10,000,000 tons, and reached the maximum of 16,111,462 tons in 1910.

The statistics of production in Alabama from 1840 to the close of 90 are found in the following table:

Production of Coal in Alabama from 1840 *to* 1910. *in short tons.*

Year.	Quantity.	Year.	Quantity.	Year.	Quantity.	Year.	Quantity.
1840.....	946	1859.....	9,000	1878.....	224,000	1897.....	5,893,770
1841.....	1,000	1860.....	10,200	1879.....	280,000	1898.....	6,535,283
1842.....	1,000	1861.....	10,000	1880.....	323,972	1899.....	7,593,416
1843.....	1,200	1862.....	12,500	1881.....	420,000	1900.....	8,394,275
1844.....	1,200	1863.....	15,000	1882.....	896,000	1901.....	9,099,052
1845.....	1,500	1864.....	15,000	1883.....	1,568,000	1902.....	10,354,570
1846.....	1,500	1865.....	12,000	18854....	2.240,000	1903.....	11,654,324
1847.....	2,000	1866.....	12,000	1885.....	2,492,000	1904.....	11,262.046
1848.....	2,000	1867.....	10,000	1886.....	1,800,000	1905.....	11,866.069
1849.....	2,500	1869.....	10,000	1887.....	1,950,000	1906.....	13,107.963
1850.....	2,500	1869.....	10,000	1888.....	2,900,000	1907.....	14,250,454
1851.....	3,000	1870.....	11,000	1899.....	3,572,983	1908.....	11,604,593
1852.....	3,000	1871.....	15,000	1890.....	4,090,409	1909.....	13,703,450
1853.....	4,000	1872.....	16,800	1891.....	4,759.781	1910.....	16,111,462
1854.....	4.500	1873.....	44,800	1892.....	5,529,312		
1855.....	6.000	1874.....	50,400	1893.....	5,136,935	Total..	206,153,815
1856.....	6,800	1875.....	67,200	1894.....	4,397,178		
1857.....	8,000	1876.....	112,000	1895.....	5,693,775		
1858.....	8,500	1877.....	196,000	1896.....	5,748,697		

The following table shows the rank of Alabama in 1909 and 1910, among the ten leading coal-producing states:

Rank of first ten coal-producing States in 1909 *and* 1910, *with quantity and value of product and percentage of each.*

1909.

Production.				Value.			
Rank.	State or Territory.	Quantity. (short tons)	% of total prodn.	Rank.	State or Territory.	Value.	% of total value.
1	Pennsylvania:			1	Pennsylvania:		
	Anthracite	81,070,359	17.6		Anthracite	$149,181,587	26.9
	Bituminous	137,966,791	29.9		Bituminous	130,085,237	23.4
2	West Virginia	51,849,220	11.2	2	Illinois	53,522,014	9.6
3	Illinois	50,904,990	11.0	3	West Virginia	44,661,716	8.1
4	Ohio	27,939,641	6.1	4	Ohio	27,789,010	5.0
5	Indiana	14,834,259	3.2	5	Alabama	16,306,236	2.9
6	Alabama	13,703,450	3.0	6	Indiana	15,154,681	2.7
7	Colorado	10,716,936	2.3	7	Colorado	14,296,012	2.6
8	Kentucky	10,697,384	2.3	8	Iowa	12,793,628	2.3
9	Iowa	7,757,762	1.7	9	Kansas	10,083,384	1.8
10	Kansas	6,986,478	1.5	10	Kentucky	10,079,917	1.8

1910.

Production.				Value.			
Rank.	State or Territory.	Quantity. (short tons)	% of total prodn.	Rank.	State or Territory.	Value.	% of total value.
1	Pennsylvania:			1	Pennsylvania:		
	Anthracite	84,485,236	16.8		Anthracite	$160,275,302	25.5
	Bituminous	150,521,526	30.0		Bituminous	153,029,510	24.3
2	West Virginia	61,671,019	12.3	2	West Virginia	56,665,061	9.0
3	Illinois	45,900,246	9.1	2	Illinois	52,405,897	8.3
4	Ohio	34,269,668	6.8	4	Ohio	35,932,288	5.7
5	Indiana	18,389,815	3.7	5	Indiana	20,813,659	3.3
6	Alabama	16,111,462	3.2	6	Alabama	20,236,853	3.2
7	Kentucky	14,623,319	2.9	7	Colorado	17,026,934	2.7
8	Colorado	11,973,736	2.4	9	Kentucky	14,405,887	2.3
9	Iowa	7,928,120	1.6	9	Iowa	13,903,913	2.2
10	Wyoming	7,533,088	1.5	10	Wyoming	11,706,187	1.9

COKE.

E. W. PARKER.

The most significant feature of the coke-making industry in Alabama, as in most of the coke-producing States in 1910, was the advance in values. The quantity of coke produced in 1910 was not materially larger than in 1909, the increase being 163,203 short tons, or 5.3 per cent, from 3,085,824 short tons to 3,249,027 short tons, but with the improved demand prices advanced from an average of $2.61 per ton in 1909 to $2.82 in 1910, and the total value increased from $8,068,267 to $9,165,821, a gain of $1,097,554, or 13.6 per cent. In quantity the production of coke in Alabama in 1910 was the largest ever made, but the value of the 1910 product was about $50,000 less than that of 1907.

Reference has been made in previous reports to the advantages possessed by Alabama in having in the iron-making district of Birmingham a home market for its output of coke. Until the last few years Alabama and West Virginia were close rivals for second place among the coke-producing States, Pennsylvania of course being first. Since 1905 West Virginia has outstripped Alabama in the quantity of coke produced, and in 1910 made 3,803,850 short tons of coke as compared with 3,249,027 tons made in the Alabama ovens. Little of West Virginia's coke is, however, supplied to local markets. Probably 98 per cent. is shipped out of the State to furnish fuel to distant iron furnaces. The effect is shown by comparisons that may be made between the values of Alabama and West Virginia cokes, for whereas the quantity of coke made in West Virginia in 1910 exceeded the Alabama product by 554,823 short tons, the value of Alabama's coke exceeded that of West Virginia by $1,811,782. The average price of Alabama coke in 1910 was $2.82; that of West Virginia was $1.93.

Of the total quantity of coke made in 1910 in Alabama, 557,148 short tons were produced in by-product retort ovens, of which there are two establishments, with a total of 280 ovens in the State. The quantity of coal used in the retort ovens was 769,212 short tons, indicating a yield of coal in coke of 72.4 per cent. The average yield in coke made by the beehive ovens was 59.8 per cent. During 1910 construction was begun on a bank of 60 Koppers by-product recovery ovens at Woodward by the Woodward Iron Co., and the Tennessee Coal, Iron & Railroad Co. began the construction of 280 ovens of the same type at Corey. These were the only new ovens under construction in the State at the close of the year.

There were 43 establishments in Alabama in 1910, the same number as in 1909. The total number of ovens increased from 10,061 in 1909 to 10,132 in 1910. These do not include the 340 Koppers ovens under construction at the close of 1910. Of the 43 establishments 5, with a total of 518 ovens, were idle during the entire year 1910. In 1909 there were 6 establishments with a total of 713 ovens idle throughout the year. The average production from the 9,614 ovens that were in operation in 1910 was 338 short tons; in 1909 the average production per oven was 330 tons.

The principal coal beds of Alabama which furnish the coal for coke making are the Pratt, the Mary Lee, and the Blue Creek, all of which are in the Warrior Basin, and the mining operations are in Jefferson, Walker, and Tuscaloosa counties. Some coking coal is also produced from the Buck or Blocton No. 1 bed, in Bibb County.

The production of coke in Alabama in 1880, 1890, 1900, and from 1906 to 1910 is shown in the following table:

Statistics of the manufacture of coke in Alabama, 1880-1910.

Year.	Establishments.	Ovens.		Coal used (short tons.)	Coke produced (short tons.)	Total value of coke at ovens.	Value of coke at ovens (per ton.)	Yield of coal in coke (per cent.)
		Built.	Building.					
1880	4	316	100	106,283	60,781	$183,063	$3.01	57.0
1890	20	4,805	371	1,809,964	1,072,942	2,589,447	2.41	59.0
1900	30	6,529	690	3,582,547	2,110,837	5,629,423	2.67	58.9
1906	42	9,731	160	5,184,597	3,034,501	8,477,899	2.79	58.5
1907	43	9,889	50	4,973,296	3,021,794	9,216,194	3.05	61.0
1908	45	10,103	0	3,875,791	2,362,666	7,196,901	3.04	61.0
1909	43	10,061	0	5,080,764	3,085,824	8,068,267	2.61	60.7
1910	43	*10,132	†340	5,272,322	3,249,027	9,165,821	2.82	61.6

* Includes 280 Semet-Solvay ovens. † Koppers by-product ovens.

About 60 per cent of the coal made into coke in Alabama in 1910 was washed slack. The total quantity of coal made into coke in 1910 was 5,272,322 short tons, of which 3,192,306 tons were washed slack. Of the other, 2,080,016 tons, 1,308,085 tons were run-of-mine coal crushed and washed before coking, and 771,931 tons were unwashed mine-run coal. The total quantity of washed coal used was 4,500,391 short tons, or 86 per cent. of all the coal made into coke.

The character of the coal used in the manufacture of coke in Alabama in 1890, 1900, and for the last five years, is shown in the following table:

Character of coal used in the manufacture of coke in Alabama. 1890-1910, *in short tons.*

Year.	Run of mine.		Slack.		Total.
	Unwashed.	Washed.	Unwashed.	Washed.	
1890	1,480,669	0	206,106	123,189	1,809,964
1900	1,729,882	152,077	165,418	1,535,170	3,582,547
1906	1,493,549	1,810,089	121,122	1,759,837	5,184,597
1907	1,020,907	1,697,913	27,433	2,227,043	4,973,296
1908	548,093	1,457,360	53,218	1,817,120	3,875,791
1909	713,992	2,153,801	0	2,212,971	5,080,764
1910	771,931	1,308,085	0	3,192,306	5,272,322

Below is a list showing the rank of the first five of the States producing coke in 1906-1910.

Rank of the first five States in production of coke. 1906-1910.

State or Territory	1906	1907	1908	1909	1910
Pennsylvania	1	1	1	1	1
West Virginia	2	2	2	2	2
Alabama	3	3	3	3	3
Illinois	14	10	9	5	4
Virginia	4	4	4	4	5

Comparison of production and value of coke in Alabama.
1909 *and* 1910.

	No. of Ovens.	Coal Charged short tons	Coke Produced short tons	Total value of Coke at Ovens.	Percent. of total U.S.value
1909	10.061	5,080,764	3,085,824	$8,068,267	8.97%
1910	10,132	5,272,322	3,249,027	$9,165,821	9.19%
Increase	71	191,551	163,203	$1,097,554	
Prcentage Increase..	.705%	3.77%	5.26%	13.60%	

GOLD AND SILVER.

H. D. M'CASKEY.

The mine production of gold in Alabama in 1910 was 1,622.16 fine ounces, valued at $33,533, and that of silver was 268 fine ounces, valued at $145. These figures show an increase in value of gold output for Alabama of $4,294, and an increase in silver output of 56 fine ounces in quantity and of $35 in value. The silver production is entirely from recovery of this metal in refining the gold. No copper ores were mined in 1910.

The production of gold and silver in Alabama in 1910 was reported from 3 deep mines and 3 gold placers. The total placer gold, all from Mud and Clear creeks, in Cleburne County, was valued at $357 in 1910, as against $69 in 1909. The deep-mine production was from 9,763 short tons of ore, with an average recoverable value per ton in gold and silver of $3.41. In 1909 the ore production was 9,886 short tons, but the recoverable value per ton was only $2.96.

The output in 1910 was again almost wholly from the Hog Mountain mines in Tallapoosa County. The siliceous ores of this mine are in part oxidized and in part sulphides, and they are treated in a 120-ton cyanide plant. There was a nominal output of gold from the Gold Ridge mines in Randolph County, and development work at the Story prospect in Talladega County yielded a small amount of siliceous smelting ore which was shipped. Dump material was also treated at this property by amalgamation in a 5-stamp mill. Operations continued for only three months in 1910. Development work was done at the Holly mines near Dadeville in Tallapoosa County.

Gold and Silver production in 1909 *and* 1910.

	Gold.		Silver.		
	Value.	Percentage of total U. S. Value	Quantity oz.	Value.	Percentage of total U. S. Value
1909	$29,239	0.029%	212	$110	0.00035%
1910	33,533	0.035%	268	145	0.00046%
Increase	4,294		56	35	
Percentage	14.68%		26.37%	31.82%	

GRAPHITE.

EUGENE A. SMITH.

This substance is very generally distributed among the metamorphic or crystalline rocks, and it occurs in two modes. In the feebly crystalline schists or slates which we have called the Talladega, and which in part, at least, are paleozoic sediments, of as late age as the Coal Meansures, the graphite is vcery often found as a sort of black graphitic clay free from grit and is frequently used as a lubricant. In this condition the graphite is very difficult to separate from the other matters with which it is mixed. Examples of this mode of occurrence are to be seen near Millerville, in Clay County, and about Blue Hill and Gregory Hill in Tallapoosa.

In the mica schists and other fully crystalline rocks of this region the graphite is present in the form of thin flakes, or *lamellae*, and is comparatively easy to separate from the enclosing rock. This variety of graphite has been worked at several points in Clay, Coosa, and Chilton Counties.

In Tallapoosa County a mile below Tallassee there is a third mode of occurrence, or perhaps a modification of the second above described. Here a belt of garnetiferous schist crosses the river in an outcrop of about 100 yards width. In this schist the graphite is found in lenses or flakes which sometimes attain a diameter of two inches. As the rock disintegrates the graphite lenses weather out and are scattered loose over the surface. The same belt or a similar one is to be seen where it crosses Wolf Creek in the northern part of Macon County.

During 1910 only two companies produced graphite in Alabama, viz.: (1) The Allen Graphite Co., whose plant is located about eight miles west of Ashland at "Graphite." (This Company was acquired in 1911 by the Quenelda Graphite Co.) (2) The Ashland Graphite Co., successor to the Enitachopco Graphite Co., whose quarry and mill are located about 4 1-2 miles west of Ashland. The graphite bearing rock at both places is a much decomposed schist consisting mainly of quartz and graphite. The character of the original rock is very difficult to determine.

This belt of graphitic schist can be followed southwestward through Coosa into Chilton County. Very promising occurrences have been noted in the vicinity of Goodwater and Hollins and near the Coosa River about Dollar P. O. in Coosa County, and across the river in Chilton County at one or two localities near Mountain Creek on the L. & N. R. R. In former years the Dixie Graphite Co. and the Flaketown Graphite Co. in this section were credited with some production of graphite, but they were idle during 1910.

In the Mineral Resources of the United States Geological Survey for the year 1910 a full account by Mr. Edson S. Bastin is given of the graphite producing plants in Clay County, together with rather full notices of the Dixie and Flaketown companies. To this article the reader who is interested in the possibilities of Alabama in this particular is referred.

Production and Value of Crystalline Graphite in Alabama in 1910.

Quantity.	Value.	Percent of total U. S. Production	Percent of total U. S. Value.
1,577,997 lbs.	$54,688	2.03%	14.49

IRON ORE.

EUGENE A. SMITH.

Iron ores of Alabama in the order of their economic importance are (1) red ore or hematite; (2) the brown ore or limonite; (3) the gray ore. The black band and clay iron stone have been noticed as occurring in a number of places, but only the red ore and the brown ore have been mined on any large scale.

Practically all the ore mined in Alabama is smelted in the State, the shipments out of the State being about equal to those received from other states.

The tables given below will show the rank of Alabama among the States of the Union both in the production of iron ore and in pig iron, and will show also the quantity of iron produced by charcoal and by coke respectively as fuels.

RED ORE OR HEMATITE.

Practically all the ore of this quality mined in Alabama occurs in the Clinton or Red Mountain formation. The Red Mountain ridges occur on each side of the anticlinal valleys which separate the coal fields. In places the red ore ridges are lacking on one side, usually the western, of the valleys being cut out by faults, while on the other hand the ridge may be duplicated on one side of the valley by the same faults.

In most of the valley occurrences the moderate dips of the ore bed are on the eastern side and there are also practically all of the ore mines. Murphrees Valley makes an exception to this, the moderate dips and the iron mines being on the western side. The iron ore occurs mainly in the central part of the formation in seams or beds one to five in number, which vary in thickness from a few inches to thirty feet.

While the ore seams are very persistent along the outcrop which in Alabama must be as much as 50 miles, yet they vary greatly from place to place, being either too thin or too lean for profitable working in the greater part of this distance.

The most important development of the Clinton ore in this State and in the world is along the 15 or 16 mile stretch of the east Red Mountain between Birmingham and Bessemer, and there is a practically continuous series of mines and strippings for this entire distance. Much mining of this ore has also been done near Gate City, Village Springs, Attalla, Gadsden, Round Mountain, Gaylesville, Ft. Payne, Valley Head, etc.

Production and Value of Hematite in Alabama in 1909 *and* 1910.

	Quantity. Tons.	% of total U.S. Prod.	Value.	% of total U.S. Value
1909	3,176,416	6.87%	$3,389,206	3.38%
1910	3,678,139	7.12%	4,376,555	3.39%
Increase	501,723		987,349	
Percent.	15.79%		29.13%	

The average price per long ton of hematite ore in Alabama was, in 1909, $1.07; in 1910, $1.19.

BROWN ORE OR LIMONITE.

This ore, the second in importance in the State and in the United States, furnished only 5.04 per cent of the total iron ore production of the United States in 1910. Of this Alabama produced 39.15 per cent., 1,123,136 long tons, and the State holds the *first* rank in this industry.

In the early days of iron making and up to the year 1876 this was the only ore used in the catalan forges, bloomaries, and charcoal furnaces of the State. It was then demonstrated that good iron could be made at low cost from the red ores, with coke for the fuel.

In general the limonites are considered the best of the ores of Alabama and they command the highest prices and command a ready sale.

The usual mode of occurrence is in irregular masses of concretionary origin in the residual clays resulting from the decomposition of limestones, and as a consequence the mining is uncertain and expensive. Limonite also occurs in regularly stratified seams or beds, and then it is the result of the alteration of pyrites or of carbonate ores. Practically all of the brown ore actually mined is that occurring in the residual clays above mentioned. Most of the ore before going to the furnace is washed and screened, and this manipulation, together with the cost of mining, makes it the most expensive of the iron ores, and it is therefore seldom used alone, but is usually mixed with the red ore in proportions determined by the quality of the iron desired. It is used alone in the charcoal furnaces and also in the coke furnaces when a particularly tough pig iron is wanted.

The limonite deposits are very numerous and are distributed over a broad expanse of country and in many places are known to be very extensive. In some of the deposits the ore is in nearly solid mass, in others it is much scattered, and in consequence the amount of foreign material necessary to be moved for every ton of ore produced, varies very much, not only in the different ore banks but also in the different parts of the same bank.

The deposits occur in nearly all the geological formations of the state, but in most of these the ore is either insufficient in quantity or not pure enough to be of much commercial value. The most important of the deposits, in point of extent and value, occur overlying the following formations, viz., the Knox Dolomite and the Weisner Quartzite, the Lauderdale Chert of the Lower Carboniferous, and the Lafayette. Some extensive beds of ore of inferior quality generally, occur also in the Tuscaloosa formation of the Cretaceous, and in the upper part of the Lower Carboniferous and in the Metamorphic rocks.

The average price per long ton of limonite in Alabama was in 1909, $1.41; in 1910, $1.53.

Production and Value of Brown Ore in Alabama ***in*** **1909** ***and*** 1910.

	Quantity.	% of total U.S. Prod.	Value.	% of total U.S. Value
1909	1,144,836	42.39%	$1,607,249	35.43%
1910	1,123,136	39.15%	1,707,167	35.28%
Increase or Decrease	—21,700		+$99,918	
Percent	—1.88%		+6.21%	

In the following table the States are arranged according to their rank as producers in 1909 and 1910, with regard to both the quantity and the value of the iron ore produced:

Rank of first five iron-ore producing States in 1909 *and* 1910, *with quantity and value of product and percentage of each.*

1909.

Rank	State.	Production.		Rank	State.	Value.	
		Quantity, in long tons.	Percentage of total product'n			Amount.	Percentage of total value.
1	Minnesota	28,975,149	56.64	1	Minnesota	$60,253,314	54.79
2	Michigan	11,900,384	23.26	2	Michigan	32,282,622	29.36
3	Alabama	4,321,252	8.45	3	Alabama	4,996,455	4.54
4	Wisconsin	1,067,436	2.09	4	New York	3,072,323	2.79
5	New York	1,015,333	1.98	5	Wisconsin	2,727,406	2.48

1910.

1	Minnesota	31,966,769	56.19	1	Minnesota	$78,462,560	55.75
2	Michigan	13,303,906	23.39	2	Michigan	41,393,585	29.41
3	Alabama	4,801,275	8.44	3	Alabama	6,083,722	4.32
4	New York	1,287,209	2.26	4	New York	3,848,683	2.74
5	Wisconsin	1,149,551	2.02	5	Wisconsin	3,610,349	2.57

Production of Iron Ore in Alabama in 1909 *and* 1910.

	Hematite (long tons)	Brown ore (long tons)	Total Quantity.	Value.	% of total U. S. Value.
1909	3,176,416	1,144,836	4,321,252	$4,996,455	4.54
1910	3,678,139	1,123,136	4,801,275	$6,083,722	4.32
Increase or Decrease ...	+501,723	—21,700	+480,023	+$1,087,267	
Per cent	+15.79	—1.89	+11.11	+21.67	

Kinds of Ore Produced in Alabama, and Values of same in 1909 *and* 1910.

	Hematite				Brown Oore				Total.		Percent of U. S. Total	
	Quantity long tons	% of total	Value	% of total	Quantity long tons	% of total	Value	% of total	Quantity long tons	Value	Quantity	Value
1909	3,176,416	73.73	$3,389,206	67.85	1,144,836	26.26	$1.607,249	32.15	4,321,252	$4,996,455	8.44	4.54
1910	3.678,139	76.6+	$4,376,555	71.93+	1,123,136	23.39+	$1,707,167	28.07+	4,801,275	$6,083,722	8.43	4.32
Increase or Decrease	+501,723		+$987,349		—21,700		+$99,918		+480,023	+$1,087,267		
Per cent	+15.79%		+29.13%		—1.88%		+6.21%		+11.11%	+21.76%		

Rank of Groups producing over 50,000 Tons.
(Alabama Mines.)

	Name of Mine.	Nearest Town	Variety of ore	Quantity.
1	Red Mountain Group	Bessemer	Hematite	1,769,067
2	Woodward	Woodward	Hematite	456,959
3	Songo	Birmingham	Hematite	189,527
4	Crudup	Gadsden	Hematite	164,250
5	Greeley	Greeley	Brown Ore	145,210
6	Woodstock	Woodstock	Brown Ore	127,647
7	Raimund No. 1.	Bessemer	Hematite	118,675
8	Raimund No. 2	Bessemer	Hematite	100,741
9	Steinman	Birmingham	Hematite	78,557
10	Houston	Woodstock	Brown Ore	75,554
11	Champion	Oneonta	Brown Ore	67,024
12	Spalding	Birmingham	Hematite	58,750
13	Stegmiller	Birmingham	Hematite	54,403
14	Tecumseh	Tecumseh	Brown Ore	50,964
			Total	3,457,318

PIG IRON AND STEEL.

The following table shows the quantity and approximate value of pig iron production in the United States in 1909 and 1910, and the increase or decrease, both by totals and percentages, for the first five producing States:

Quantity and value of pig iron produced in the United States in 1909 and 1910 by first five States, in long tons.

	State	1909		1910		Increase (+) decrease (—) in 1910.		Percentage increase (+) or decrease (—) in 1910.	
		Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value
1	Penn'a.	10,918,824	$175,429,000	11,272,323	$180,695,338	+353,499	+$5,266,338	+ 3.24	+ 3.00
2	Ohio	5,551,545	93,321,000	5,752,112	88,122,356	+200,567	— 5,198,644	+ 3.61	— 5.57
3	Illinois	2,467,156	44,211,000	2,675,646	42,917,362	+208,490	— 1,293,638	+ 8.45	— 2.93
4	Alabama	1,763,617	22,222,000	1,939,147	23,754,551	+175,530	+ 1,532,551	+ 9.95	+ 6.90
5	New York	1,733,675	27,392,000	1,938,407	32,410,165	+204,732	+ 5,018,165	+11.81	+18.32

Production of pig iron in Alabama, 1907-1910.

J. M. Swank.

	Coke Pig Iron Long tons	Charcoal Pig Iron Long tons	Total Long tons
1907	1,651,533	35,141	1,686.725
1908	1,373,199	23,815	1,397,014
1909	1,729.976	33.641	1,763,617
1910	1,903.443	35,704	1.939.147
1911	1,679.886	32,557	1.712,443

Alabama Production of Rolled Iron and Steel (including Rolled Forging Blooms and Rolled Forging Billets) from 1907 *to* 1910 *inclusive.*

J. M. Swank.

Year.	Iron	Steel	Total
1907	44,728	238.569	283,297
1908	4,417	269.235	273,652
1909	1,267	256,705	257,972
1910	6,419	420,052	426,471

LIME.

C. A. ABELE.

The total production of fourteen operators in 1910 was 81,696 short tons, an increase over 1909 of 6,428 tons or 8.54 per cent. The value of the product was $303,612, an increase of 13,553, or 4.67 per cent.

Production and value of lime in 1909 and 1910, and a comparison of these years:

Production of Lime in 1909 *and* 1910.

	No. of Operators.	Quantity Short tons	Value.	Av'g price per ton.	Percentage of total U. S. Value.
1909	16	75,268	$290,059	$3.85	2.08%
1910	14	81,696	$303,612	$3.72	2.19%
Increase	......	6,428	$13,553	....	....
Percentage	......	8.54%	4.67%	....	....

The most important use of the lime produced in this State is for building purposes, though a large percentage is used in chemical plants, sugar refineries, etc., or is handled by dealers. Though at present only a small part of the Alabama production is used in chemical processes, this use may in time create a greater market in this State.

Below is an outline of some of the chemical processes in which lime may be used.

Chemical Uses of Lime.

E. F. Burchard.

- Agricultural industry:
  - As a soil amendment, c, m,[1]
  - As an insecticide, c, m.
  - As a fungicide, c, m.
- Bleaching industry:
  - Manufacture of bleaching powder, "Chloride of lime," c.
  - Bleaching and renovating of rags, jute, ramie, and various paper stocks, c, m.
- Caustic alkali industry:
  - Manufacture of soda, potash and ammonia, c.
- Chemical industries:
  - Manufacture of ammonia, c.
  - Manufacture of calcium carbide, calcium cyanimid and calcium nitrate, c.
  - Manufacture of potassium dichromate and sodium dichromate, c.
  - Manufacture of fertilizers, c, m.
  - Manufacture of magnesia, m.
  - Manufacture of acetate of lime, c.
  - Manufacture of wood alcohol, c.
  - Manufacture of bone ash, c. m.
  - Manufacture of calcium carbides, c.
  - Manufacture of calcium light pencils, c.
  - In refining mercury, c.
  - In dehydrating alcohol, c.
  - In distillation of wood, c.
- Gas manufacture:
  - Purification of coal gas and water gas, c. m.
- Glass manufacture:
  - Most varieties of glass and glazes, c.
- Milling industry:
  - Clarifying grain, c, m.
- Miscellaneous manufactures:
  - Rubber, c, m.
  - Glue, c, m.
  - Pottery and porcelain, c, m..,
  - Dyeing fabrics, c, m.
  - Polishing material c, m.
- Oil, fat, and soap manufacture:
  - Manufacture of soap, c.
  - Manufacture of glycerine, c.
  - Manufacture of candles, c.
  - Renovating fats, greases, tallow, butter, c, m.
  - Removing the acidity of oils and petroleum, c, m.
  - Lubricating greases, c, m.
- Paint and varnish manufacture:
  - Cold-water paint, c, m.
  - Refining linseed oil, c, m.
  - Manufacture of linoleum, c, m
  - Manufacture of varnish, c, m.
- Paper industry:
  - Soda method, c.
  - Sulphite method, m.
  - For strawboard, c, m.
  - As a filler, c, m.
- Preserving industry:
  - Preserving eggs, c.
- Sanitation:
  - As a disinfectant and deodorizer, c.
  - Purification of water for cities,c.
  - Purification of sewage, c.
- Smelting industry:
  - Reduction of iron ores, c, m.
- Sugar manufacture:
  - Beet root, c.
  - Molasses, c.
- Tanning industry:
  - Tanning cowhides, c.
  - Tanning goat and kid hides, c, m.
- Water softening and purifying, c.

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[1] High calcium lime is indicated by "c," magnesian and dolomitic lime by "m."

MINERAL WATERS.

G. C. MATSON.

According to the returns received from spring owners, the mineral-water trade of Alabama continued to prosper during 1910, sales increasing from 116,645 gallons reported during 1909 to 133,159 gallons in 1910, an increase of 16,514 gallons, or a little over 14 per cent. The value, however, owing to a decline of 2 cents per gallon in the average price for the year, increased only 7 per cent, or from $28,595 in 1909 to $30,639 in 1910. There were no new springs reporting during 1910, and one which sold a considerable quantity during 1909 changed ownership during the year and could not furnish data, thus decreasing the total number of springs from 10 to 9. About three-fourths of the total sales of mineral water in Alabama is used medicinally. There are resorts at 6 of the springs, accommodating more than 1,000 people, and the water at 3 is said to be used for bathing purposes. In addition to the quantity reported as sold, there were 10,500 gallons used for the manufacture of soft drinks.

The following list of 9 springs reported sales:

Bailey Springs, Florence, Lauderdale County.
Bromberg Gulf Coast Lithia Springs, Bayou La Batre, Mobile County.
Healing Springs, Healing Springs, Washington County.
Ingram Lithia Wells, near Ohatchee, Calhoun County.
Livingston Mineral Springs, Livingston, Sumter County.
Luverne Mineral Spring, Luverne, Crenshaw County.
MacGregor Springs, Spring Hill, Mobile County.
Magnolia Spring, Magnolia Springs, Baldwin County.
Matchless Mineral Wells, east of Greenville, Butler County.

The following table shows the increase in the value of the mineral waters produced in 1910, over the value of those produced in 1909.

Production of Mineral Waters in **1909** *and* **1910.**

	No. of Springs.	Quantity Sold (gal.)	Average retail price.	Value of Medicinal Waters.	Value of Table Waters.	Total Value of Mineral Waters.	Percentage of Total U. S. Value.
1909	10	116,645	$0.25	$21,208	$7,387	$28,595	0.41%
1910	9	133,159	$0.23	$23,179	$7,460	$30,639	0.48%
Increase	......	16,514	....	$ 1,971	$ 73	$ 2,044	....
Percentage	......	14.15%	....	9.29%	0.99%	7.15%	....

Since 1910 a number of other Mineral waters have been reported and will be taken into account in the statistics of 1911 and following years.

SAND AND GRAVEL.

C. A. ABELE.

The total production of sand and gravel in the State in 1910 was 307,715 short tons, valued at $100,261, as compared with 307,456 short tons, valued at $109,478 in 1909, a net increase in quantity of 259 short tons, or .084 per cent., and a decrease in value of $9,217, or 8.42 per cent.

The following tables give the production, value, and uses of the sand and gravel in 1909 and 1910, and a comparison of these years:

Production and Value of Sand in 1909 *and* 1910.

	Molding Sand		Building Sand		Engine Sand		Furnace Sand		Other Sand		Total	
	Quantity tons	Value	Quantity tons	Value	Quantity tons	Value	Quantity tons	Value	Quantity tons	Value	Quantity tons	Value
1909	119,999	$57,236	169,567	$49,249	6,510	$1,993	100	$50	1,280	$950	307,456	$109,478
1910	56,085	22,069	228,797	73,567	6,350	1,930	286	148	16,197	2,547	307,715	100,261
Increase or Decrease	—63,914	—35,237	+59,230	+14,318	—160	—.63	+186	+98	+14.917	+1,397	+259	—9,217
Per cent	— 53.26	—61.54	+35.52	+29.08	—2.46	—0.34	+186.0	+196.	+1,173.2	+147.05	+0.084	—8.42

Production and Value of Sand and Gravel in 1909 *and* 1910.

	Gravel		Sand		Total		% of Total U. S. Value
	Quantity tons	Value	Quantity tons	Value	Quantity tons	Value	
1909	314,322	$104,918	307,456	$109,478	621,778	$214,396	1.16%
1910	311,538	87,330	307,715	100,261	619,253	187,591	.89%
Increase or Decrease	—2,774	—17,588	+259	—9,217	—2,525	—26,805	......
Per cent	—0.88	—16.76	+0.084	—8.42	—0.406	—12.5	......

STONE.

E. F. BURCHARD.

The figures presented in the following report have to do with the stone produced and sold by the quarrymen and include only such manufactured product as is put on the market by the quarrymen themselves. This applies especially to rough and dressed building stone, dressed monumental stone, crushed stone, flagstone, curbstone, and paving blocks. The value given to this manufactured product is the price received by the producer, free on board at point of shipment, and includes therefore the cost of labor necessary to dress the stone. The stone reported as sold rough includes stone sold as rough stock to monumental works, and to cut-stone contractors for building purposes; stone sold as riprap, rubble, and flux; and includes the value of only such labor as is required to get the stone out of the quarry in the shape required by the purchaser. The value given to this stone is the price received by the quarryman free on board at point of shipment. In case the stone is sold to local trade the value is given as the quarryman sells the material, generally at the quarry, but in some cases delivered, if this is done by the producer. In some instances a long haul to market or to the railroad increases the cost of the material, and therefore of the selling price.

UNIT OF MEASUREMENT.

Owing to the variety of uses to which stone is put there is no regular unit of measurement employed by the quarrymen, the stone being sold by the cubic yard, the cubic foot, the ton, cord, perch, rod, square foot, square yard, square, etc. Building and monumental stone, especially the dressed product, is usually sold by the cubic foot or the cubic yard, although this unit varies with the class of stone and with the locality; a large quantity of the rough stone is sold by the perch, cord and ton. Rubble and riprap, including stone for heavy masonry, such as breakwater and jetty work, are generally sold by the cord and ton. Fluxing stone and stone for chemical use—as for alkali works, sugar factories, carbonic-acid plants, paper mills, etc.—are sold by the long ton. Flagstone and curbstone are sold by the square yard and the square foot, the thickness being variable and depending on the order received by the quarrymen. Paving blocks are sold invariably by number of blocks, and as such have been tabulated and published for several years; these blocks, however, are not of uniform size, the value depending on the size and amount of labor necessary to cut the block into the shape desired. Crushed stone is reported as sold by the cubic yard or ton, the short ton being more generally used. The weight of a cubic yard varies from 2,300 to 3,000 pounds, the average weight being 2,500 pounds. In certain localities this crushed stone is sold by the "square" of 100 square feet by 1 foot, or 100 cubic feet to a square. It is also of interest to note the selling of crushed stone by the bushel, 21 1-2 bushels reperesenting a cubic yard of about 2,700 pounds. As most of the crushed-stone producers report the quantity according to some unit, it has been possible to convert the crushed stone into short tons, which unit represents the larger number of producers and is the most convenient.

LIMESTONE.

This report does not include the value of the stone burned into lime, nor of that used in the manufacture of Portland cement. The former values are given under the heading, Lime; the latter are included in the value of the cement.

As thus limited the total value of limestone produced in 1910 was $714,516, as compared with $700,642 in 1909, an increase of $13,874.

The values from 1906 *to* 1910 *are given below for comparison.*

1906	1907	1908	1909	1910
$579,344	$694,699	$479.730	$700,642	• $714.516

The values of limestone produced in 1909 and 1910, classified according to the uses may be seen in the following table:

Values of Limestone Produced in 1909 *and* 1910.

	1909	1910	Increase or Decrease	Per cent
Rough Building	$ 775	$ 1.901	$ +1.126	+145.29%
Dressed Building	27,197	34,001	+6,804	+ 25.01%
Paving	2,000	4.500	+2.500	+125.00%
Curbing	46,115	....	....	....
Rubble	8,460	....	....	....
Riprap	19,200	37,505	+18,305	+95.34%
Road Making	60,452	64,872	+4.420	+7.24%
Railroad Ballast	5,521	5.842	+321	+5.81%
Concrete	16,825	16,199	—626	—3.72%
Flux	512,585	545.988	+33.403	+6.51%
Other	*1,512	3,708	+2,196	....
Total	$700,642	$714.516	+$13,874	+1.98%
Percentage of total U. S. value	2.18	2.62	....	....

* Includes limestone for agricultural purposes.

LIMESTONE FOR BUILDING PURPOSES.

EUGENE A. SMITH.

From the tables above it will be seen that by far the largest part of the limestone for other purposes than lime burning produced in Alabama 1909-1910, has been for flux rock in the iron furnaces. Crushed stone for road making and riprap follow next, and then dressed building stone.

The preparation of cut stone for building purposes in Alabama, while on the increase, is not yet what it should be. Practically all of this material comes from the quarries in the Subcarboniferous limestone of the Tennessee Valley, the most important quarries being at Rockwood in Franklin County, operated by Foster-Creighton-Gould Co., of Nashville. This stone is quite similar in appearance, composition, and other qualities to the Indiana stone, and so far as experience in the use of the stone from the two localities in the buildings of the University of Alabama goes, the Alabama stone holds its own under influence of the weather better than does the Indiana stone. Stone steps, door sills, and window sills, buttress caps, etc., of the Alabama stone put in place in 1885 show practically no deterioration in color and wear under foot, and in crumbling and roughening under the influence of the weather, which can not be said of some portions of the Indiana stone used in buildings erected in 1909-10. The Rockwood quarries have most modern and approved methods of machinery for sawing the stone and handling it in transit to the mills and elsewhere. The stone is of massive formation, of great thickness and extent. Blocks weighing as much as 25 tons, without crack or flaw, are not infrequently quarried, the size of the blocks being practically limited only by the capacity of the hoisting machinery.

The Oolitic variety is most extensively used for building and monumental work. It is of light gray color, uniform grain, and homogeneous texture. It possesses a quality of cheapness, it can be cut to any design required, and is at the same time strong and durable.

At the present time the business at this quarry is confined to the furnishing of rough and sawed stone to the cut stone contractor or dealer.

With the installing of adequate machinery at the quarry for doing the finished work, there should never be any longer any reason for going outside of the State for this quality of stone. Already the material has been very extensively used in public buildings in Mississippi, Tennessee, as well as in Alabama. The only reason why it was not used in the recently erected buildings at the University of Alabama was that at the time these building contracts were let, the quarries furnished only the rough sawn stone and there was not in Alabama any establishment adequately equipped for the dressing of the stone in the quantity needed.

MARBLE.

EUGENE A. SMITH.

The marble of Alabama is of two kinds, crystalline or true marble and non-crystalline.

The cystalline or statuary marble occurs mainly in a narrow valley along the western border of the metamorphic area, extending from Marble Valley in Coosa County, through Talledega into Calhoun. The outcrops have a width of about a quarter of a mile and a length of 60 miles at least.

The best of these occurrences as yet known are in Talladega County and the principal quarries from which the stone has been obtained are Gantt's and Herd's near Sylacauga, Nix's near Sycamore, and Taylor's and McKenzie's near Taylor's Mill east of Talladega. From all these marble was quarried before the Civil War. The only establishment actually producing marble in 1910 was the Alabama Marble Co. af Gantt's a few miles southwest of Sylacauga. This establishment has a plant with a capacity of something over 200,000 cubic feet per year, and its marble has been used in more than 140 important buildings throughout the United States. The marble from this place is now well established as a material fully equal if not superior to the imported Italian marbles. It can be seen in the new National Museum in Washington. The mill was destroyed by fire in 1910, but has since been rebuilt on a larger scale.

The Talladega Marble Company with quarries near Taylor's Mill, was idle in 1910, but preparations are in progress for starting up the quarries soon.

Mr. Bishop, near Marble Valley south of Talladega Springs has recently exposed a fine body of marble, and expects soon to begin operations. The Scott Brothers near the old Nix Quarry not far from Sycamore, have also exposed a fine body and have many drill cores proving the superior quality of the marble as well as its very considerable thickness.

A beautiful quality of variegated limestone or marble—red, pink, and white—belonging probably to the Cambrian formation, occurs in Shelby County a mile or two south of Shelby Springs station on the L. & N. railroad, and extending thence southwest for a mile or two. Nothing but prospecting work has been done on this marble. The Trenton limestone in the Appalachian valleys, particularly Jones Valley below Bessemer, contains marble quarried in the vicinity of Knoxville. Also at Pratt's ferry on the Cahaba River in Bibb County a quarry was for many years worked in this formation and turned out a very beautiful quality of marble varying in color from gray through pink, red, and brown shades.

In the Coastal Plain the St. Stephens limestone of the Tertiary holds ledges of hard, almost crystalline rock capable of taking good polish. The colors vary from nearly white, through shades of yellowish into red, and it would make a handsome decorative marble, especially for inside work.

Other limestone formations, such as the Subcarboniferous and the Knox Dolomite, could in places be drawn upon for marble.

SANDSTONE.

The value of the sandstone produced in Alabama from 1906 to 1910 is shown below, the increase in 1910 over 1909 being $31,736.

Value of Sandstone production from 1906 *to* 1910.

1906	1907	1908	1909	1910
$40,467	$48,673	$34,099	$77,327	$109,063

Value and Uses of Sandstone Produced in 1909 *and* 1910.

	Rough Building	Ganister	Rubble	Riprap	Concrete	Other	Total	% of Total Value.
1909	$ 3,951	......	$15,347	$325	$51,432	[*]$,6272	$77,327	0.96%
1910	100	$12,088	20,802	20,073	56,000	......	109,063	1.37%
Increase or Decrease	—3,851	......	+5,455	+19,748	+4,568	......	+31,736	......
Per cent	—96.2%	......	+35.54%	+607.62%	+8.88	......	+40.78	......

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[*] Includes dressed building stone (one producer.)

FUTURE PROBABLE PRODUCTION.

The following minerals have been produced in Alabama in past years, but no production was reported for 1910; Fullers Earth, Manganese ore, Mica, Ocher, Pyrite. Since all these occur in quantity and of quality to make them of commercial value, the production may be resumed at any time.

Among the probable productions in the near future, are natural gas and petroleum, onyx marble, turquoise and other minerals noticed in the Index to the Mineral Resources of Alabama a publication of the State Geological Survey.

Natural gas under pressure of 630 pounds has been obtained from several wells in Fayette County, and smaller quantities under less pressure have been obtained near Huntsville and elsewhere.

A Report with map on the Fayette County Gas Field has been published by the survey during the past year. No commercial production has yet been reported.

GEOLOGICAL SURVEY OF ALABAMA

EUGENE ALLEN SMITH, *State Geologist*

BULLETIN No. 13

STATISTICS OF THE MINERAL PRODUCTION OF ALABAMA FOR 1911

COMPILED FROM MINERAL RESOURCES OF THE
UNITED STATES

By
CHARLES ARTHUR ABELE

UNIVERSITY, ALABAMA
1913

PRESS
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ALABAMA

LETTER OF TRANSMITTAL.

UNIVERSITY, ALA., March, 1913.

HON. EMMET O'NEAL,
Governor of Alabama,
Montgomery, Ala.

SIR:—I have the honor to transmit herewith the manuscript of a Report on the Mineral Production of Alabama for the year 1911, with the request that it be printed as Bulletin No. 13 of the Geological Survey of Alabama.

Very respectfully,
EUGENE A. SMITH,
State Geologist.

GEOLOGICAL CORPS.

Eugene Allen Smith, Ph. D	State Geologist
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Robert S. Hodges	Chemist
Herbert H. Smith	Curator of Museum
Roland M. Harper	Botanist
George N. Brewer	Field Assistant
Charles Arthur Abele	Clerk in charge of Statistics of Mineral Production
James A. Anderson	Clerk in charge of Mailing List
A. T. Donoho	Stenographer

RIVER GAGE HEIGHT OBSERVERS.

C. J. Stowe	Jackson's Gap, Tallapoosa River
J. E. Whitehead	Riverside, Coosa River
George Havens	Epes, Tombigbee River
W. G. Early	Pera, Pea River
S. T. Dillard	Beck, Conecuh River

From the records of daily observations of the gage readings at these places when extended through sufficient time, the calculations of available horsepower to be obtained from the different streams is made.

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PREFACE.

The statistics of all the minerals included in the following pages have been collected in cooperation with the United States Geological Survey, and have been compiled by Mr. Abele from advance chapters of the *Mineral Resources of the United States*, a publication of the Federal Survey.

The introductory and general matter in each of these articles has either been taken without change from the U. S. advance chapters or has been rearranged or condensed from these chapters, or entirely rewritten to suit it for our present purposes. In each case credit is given to the author.

INTRODUCTION.

THE following article by Mr. E. W. Parker, of the United States Geological Survey, gives a summary of the Mineral Production of Alabama, and brings out the relation which this State holds to other states in the quantity and value of the mineral products of the Nation. *

As Pittsburgh, Pa., is the "Birmingham" of the western hemisphere, so Birmingham, Ala., is the "Pittsburgh" of the Southern States. The occurrence of the iron ores, coking coals, and limestones in close proximity in the vicinity of Birmingham enables that district to produce iron at less cost than any other region of the world. It has followed, therefore, that in years of depression of the iron trade, as in 1911, the ill-effects are exhibited less in Alabama than in other iron-making sections of the country, while in years of plenty Alabama benefits nearly as much as other States. In 1911, for instance, the total percentage of decrease from 1910 in the production of iron ores for the United States was 27.95, while Alabama's output decreased 17.61 per cent. The value of the iron ores produced in the United States in 1911 was 38.59 per cent less than in 1910; the value of Alabama's ores fell off scarcely half as much in proportion, or 19.85 per cent. In 1910, on the other hand, the total increase in the production of iron ores was 11.21 per cent, and Alabama gained 11.11 per cent, while the percentages of increases in value were, respectively, 27.98 and 21.76. Alabama ranks third among the states in the production of iron ores, and fifth in the manufacture of pig-iron, but it must be remembered that the two States, Minnesota and Michigan, which lead Alabama in the production of iron ores, are relatively unimportant in the manufacture of iron, while three of the States (Pennsylvania, Ohio, and Illinois) which exceed it in the quantity and value of pig-iron produced, obtain their ores from the Lake Superior Region, while New York secures at least half of its ores from the same source. As a producer of iron ores for home con-

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***Manufacturers' Record, Feb. 13, 1913.**

sumption, and as a manufacturer of pig-iron from its own ores, Alabama stands alone.

As a producer of coal, Alabama ranks fifth among all the States, and second in the Southern group. In the quantity of coke made, Alabama and West Virginia are usually in a neck-and-neck race, West Virginia sometimes leading, as in 1910, and Alabama again taking first place, as in 1911. When the value of coke is considered, however, Alabama takes precedence, for although the West Virginia is of better quality, the home markets give to the Alabama operators a marked advantage in the prices obtained for their output. Coal represented 68 per cent of the total of $28,000,000 worth of mineral products obtained in Alabama in 1911. The value of the iron ores was 17 per cent of the total; the clay working industries added 7 per cent; and the quarry products, principally limestone, lime, and marble, 4.5 per cent. Another 2 per cent is represented by the value of cement produced. Alabama produces a small amount of silver and gold; and other products of minor importance are bauxite, graphite, mica, millstones, mineral waters, natural gas, sand and gravel.

The discrepancy between the above total value and that given in our summary is due to the fact that we have used the value of the pig iron produced, instead of the value of the iron ore mined.—E. A. S.

STATISTICS OF THE MINERAL PRODUCTION OF ALABAMA FOR 1911.

ABRASIVES.

EUGENE A. SMITH.

ALABAMA'S production of abrasives is at present limited to a small number of millstones; but there are several materials in different parts of the state which are sufficiently promising to be worth investigation and thorough testing.

Infusorial or Diatomaceous Earth.—This material is of organic origin, being composed, in part at least, of the siliceous tests or shells of microscopic organisms both animal and vegetable. A diatomaceous earth with considerable admixture of clay and other impurities, occurs abundantly in many localities in the lower part of the State. As, for instance, in the recent swamp deposits near Mobile and in the second bottom deposits of the Alabama River at Montgomery. These are fresh water deposits.

In the Buhrstone and Clayton formations of the Tertiary there are very heavy deposits of diatoms, radiolaria and similar forms of marine origin. The Buhrstone material is a light, somewhat porous substance very high in silica, 86.3 per cent. A somewhat similar material, that is, a light porous substance having much the appearance of flint clay, occurs abundantly at Clayton and other nearby localities in Barbour County.

Polishing powder or Tripoli of very different origin, occurs in many localities in North Alabama. This is a light, porous material known as rotten stone and consisting of finely divided siliceous matter, the result of the thorough leaching of the cherty limestone and dolomite formation of the Lower Silurian and of the Ft. Payne division of the Lower Carboniferous. The Tripoli found in the Knox Dolomite is usually a coherent rock, whilst the sub-Carboniferous material is often a pulverulent substance of pure white color like flour. Both these forms of Tripoli are essentially pure silica or with very slight admixture of clay. The solid masses need to be crushed, ground and bolted preparatory to using, while the pulverulent form would probably require no manipulation beyond passing through a fine mesh sieve or bolting.

The Knox Dolomite tripoli is most abundant in the Coosa Valley region, especially Calhoun and Talladega counties, while the pulverulent and other material of the Sub-carboniferous is most abundant in the Tennessee Valley, in Lauderdale and Limestone Counties.

A specimen of very white fine powder of 99.4 per cent silica has recently been received from Geneva County. If this deposit should be found of sufficient thickness and easy of access, it should find a market.

BAUXITE.

W. C. PHALEN.

USES.

THE chief uses of bauxite were outlined in this report for 1910, as follows: (1) As raw material in the production of metallic aluminum; (2) in the manufacture of aluminum salts; (3) in the manufacture of bauxite bricks; (4) in the manufacture of alundum (fused alumina) for use as an abrasive. The use of bauxite in the manufacture of calcium aluminate to give a quick set to plaster compositions should be added, as well as the extended use which alundun is finding in the refractory industries. The two latter uses are described in detail farther on.

1. The use of bauxite in the production of metallic aluminum is by far the most important of those enumerated above. A large part of the entire output of Arkansas is used in the metallic aluminum industry, and the figures of production from this State have shown phenomenal growth during recent years. A large part of the French product is also used in the manufacture of metallic aluminum.

2. Only the purer bauxite is used in the manufacture of chemicals, such as alum, aluminum sulphate, and aluminum salts in general. Freedom from oxide of iron is essential in the material to be used in the chemical manufactures.

3. The use of bauxite in the manufacture of refractory brick has by no means reached a perfected stage, but it is understood that several manufacturers are now experimenting on processes in which it is admixed with other materials. The life of bauxite-brick linings is as yet undetermined, though it is known to exceed by far the life of silica brick or fire-clay brick. The high cost of raw material, as well as that of its manufacture, makes the ultimate cost of bauxite brick excessive as compared with that of the other two bricks mentioned.

4. Bauxite is used on a large scale in the manufacture of the artificial abrasive, alundun, at Niagara Falls. This abra-

sive is made in the electric furnace by fusing calcined bauxite. It is high in crystalline aluminum oxide, and virtually amounts to a form of artificial corundum. Its quality is under complete control, and hence it can be duplicated with ease in the various abrasive products, a factor of great importance in any successful abrasive industry. Alundum is particularly efficient in the grinding of steel.

New use for alundum.—L. E. Saunders, of the Norton Co., of Niagara Falls, has recently presented data on the value of alundum (electrically fused alumina) as a refractory. Alundum was primarily developed as an abrasive, but its resistance to heat and its other valuable qualities have led to its introduction into the field of the refractories. * * *

Use of bauxite in calcium aluminate.—Henry S. Spackman and E. W. Lazell have taken out a series of patents (Nos. 903017-903020, dated November 3, 1908) on cementitious material and its preparation, in which use is made of the mineral bauxite. The inventions relate more particularly to the preparation of plaster compositions by the incorporation in them of hydraulic calcium aluminate to give them a quick set. Hydraulic calcium aluminate compounds may be prepared by mixing in proper proportions finely ground lime and bauxite or other alumina compounds, such as kaolin or high alumina clays, high alumina slag, etc. Such mixtures may be rendered hydraulic and given a quick initial set when dried, ground, and mixed with water by calcining and sintering them. If desired, the temperature may be carried higher, so as to effect fusion.

PRODUCTION.

The following table gives the production and value of bauxite from 1889 to 1911, inclusive:

Production of bauxite in the United States, 1889-1911, by States, in long tons.

Year	Georgia	Alabama	Arkansas	Total	Value
1889	728	----------	----------	728	$2,366
1890	1,844	----------	----------	1,844	6,012
1891	3,301	292	----------	3,593	11,675
1892	5,110	5,408	----------	10,518	34,188
1893	2,415	6,764	----------	9,179	29,507
1894	2,050	9,016	----------	11,066	35,818
1895	3,756	13,313	----------	17,069	44,000
1896	7,313	11,051	----------	18,364	47,338
1897	7,507	13,083	----------	20,590	57,652
1898	----------	----------	----------	25,149	75,437
1899	15,736	14,499	5,045	35,280	125,598
1900	19,739		3,445	23,184	89,676
1901	18,038		867	18,905	79,914
1902	22,677		4,645	27,322	120,366
1903	22,374		25,713	48,087	171,306
1904	21,913		25,748	47,661	285,704
1905	15,173		32,956	48,129	240,292
1906	25,065		50,267	75,332	368,311
1907	--------------------		----------	*97,776	480,330
1908	14,464		*37,703	52,167	263,968
1909	22,227		*106,874	129,101	679,447
1910	33,096		*115,836	148,932	716,258
1911	30,170		*125,448	155,618	750,649

*Production of Tennessee included.

Production of Bauxite in 1910 and 1911.

	Quantity Tons	Value	Percentage of Total U. S. Production	Percentage of Total U. S. Value
1910	9,517	$38,068	6.39	5.31
1911	8,848	35,392	5.68	4.71
Decrease	669	2,676	----------	----------
Per cent	7.03	7.03	----------	----------

CEMENT.

EUGENE A. SMITH.

PUZZOLAN OR SLAG CEMENT.

DURING the past four years only one establishment in Alabama has been engaged in the manufacture of slag cement, using the material from the furnaces about Birmingham. The production is included in the returns for Portland cement and cannot be given separately.

PORTLAND CEMENT.

Alabama contains large supplies of limestone, chalk, clay and shale well adapted for Portland Cement manufacture, and widely distributed throughout the state. Coal and labor are abundant and cheap, transportation facilities are excellent, and many of the best limestone and chalk localities are situated on navigable rivers, giving ready access and cheap water transportation to Galveston, New Orleans, Mobile, Charleston, and other ports of the Gulf and Atlantic Coasts. This advantage of location will be immensely increased with the opening of the Panama Canal for cement plants located in Alabama will be more than a thousand miles nearer to the Isthmus than their nearest possible competitors.

The limestones and shales of the northern part of the state lie so close to each other, and above all so close to the great coal mines which must supply the fuel, that the establishment of Portland Cement plants near the coal mines would give to this industry in Alabama the same advantages which the proximity of the iron ore, the coal, and the stone has given to the iron industry, and which has placed our state beyond competition.

As a Portland cement mixture, ready for burning, consists approximately of 75 per cent. lime carbonate and 25 per cent. of clayey matter, the material furnishing the lime carbonate is necessarily of more economic importance than that from which the silica and alumina are derived. In consequence, a

Portland cement plant is usually located in the immediate vicinity of a suitable limestone, while the clay or shale required to complete the mixture may be brought some distance.

The limestones formations in North Alabama which can supply the stone adapted for use in cement manufacture are the Trenton or Pelham limestone and the Bangor or Subcarboniferous. In close proximity to both these limestone formations are the shales of the Clinton, Subcarboniferous and Coal Measures.

At the present time there are two cement plants in North Alabama, namely, the Standard Portland Cement Co., located at Leeds in Jefferson County, and the Atlantic & Gulf Portland Cement Co., located at Ragland in St. Clair County. Both of these plants make use of the hard Trenton limestone, and the Standard Cement Co., according to Burchard of the U. S. Geological Survey, uses the shale of the Clinton formation whilst the Ragland Company makes use of the shales of the Coal Measures. Up to the present time no establishment is utilizing the Bangor limestone.

In Middle Alabama the soft, chalky Cretaceous limestone of the Selma Chalk, is the material utilized by the Alabama Portland Cement Co., at Spocari, near Demopolis. The same Company makes use of residual clays overlying and derived from the weathering of the Selma Chalk. During 1911 there was no production reported from the Demopolis plant.

In Southern Alabama the St. Stephens limestone outcropping east and west across the state, furnishes excellent material for Portland Cement manufacture, using either residual clays from decomposition of the limestone, or the clays of the Grand Gulf formation which are almost everywhere in close proximity to the limestone. The Mobile Cement Co. has been for some time engaged in the building of a plant at St. Stephens, but no production has yet been reported.

The following table contains the leading facts relative to the puzzolan-cement industry for the five years 1907 to 1911, inclusive:

Statistics of the puzzolan-cement industry, 1907-1911, by States.

	1907	1908	1909	1910	1911
No. of plants reporting production:					
Alabama	1	1	1	1	1
Illinois	1	-------	-------	-------	-------
Kentucky	1	-------	-------	-------	-------
Maryland	-------	-------	-------	-------	-------
New Jersey	-------	-------	-------	-------	-------
New York*	1	-------	-------	-------	1
Ohio	2	2	2	2	1
Pennsylvania	1	1	1	1	1
Total	7	4	4	4	4
Production in barrels	557,252	151,451	160,646	95,951	93,230
Value of production	$443,998	$95,468	$99,453	$63,286	$77,786

*Includes production of Collos cement in 1911.

Production and Value of Cment (Including Puzzolan and Portland) in Alabama in 1910 and 1911.

	No. of Producers	Quantity (bbls.)	Value	Percentage of total U. S. value
1910	3	406,214	$387,600	0.56
1911	3	593,911	529,359	0.79
Increase	------------	187,697	141,759	-----------
Percentage increase	------------	46.23	36.57	-----------

CLAY AND CLAY PRODUCTS.

JEFFERSON MIDDLETON AND C. A. ABELE.

CLAY.

CLAY available for the manufacture of clay products is one of the most widely spread of our minerals. Clay miners are usually also the manufacturers of the lower-grade clays, but as the higher grades of ware are reached, the rule is that fewer and fewer manufacturers are also miners, until in the highest grades of ware the rule is that the manufacturer is not the miner of the clays that he uses. The figures given in the following tables represent clay that is mined and not manufactured by the miner, but is sold as clay. The clay thus sold is small in quantity compared with that consumed and includes mainly clay used for refractory products.

The total quantity of clay mined in Alabama, and sold as such in 1911 was 35,203 short tons, as compared with 75,082 short tons in 1910, a decrease of 39,879 short tons, or 53.11 per cent. The value of the clay mined in 1911 was $29,909, a decrease from 1910 of $8,134, or 21.38 per cent. Fire clay was the only kind of raw clay produced in the state in 1911, and even this was 19,279 short tons short of the 1910 production, which was 54,482 short tons. The decrease in the value of the fire clay was $2,484, or 7.66 per cent.

Quantity and Value of Clay Produced in 1911.

Kind	Quantity Produced Short Tons	Value	Aver'g. Value per ton	Percentage of Total U. S. value
Fire Clay	35,203	$29,909	$0.821	0.859

No other variety of clay was produced.

Comparison of Clay Production in 1910 and 1911.

	Fire Clay		Miscellan. Clay		Total	
	Quantity Short Tons	Value	Quantity Short Tons	Value	Quantity Short Tons	Value
1910	54,482	$32,395	20,600	$5,650	75,082	$38,045
1911	35,203	29,909	-------	-------	35,203	29,909
Decrease	19,279	2,484	-------	-------	39,879	8,134
Per cent.	35.38	7.66	-------	-------	53.11	21.38

No production of Miscellaneous Clay in 1911.

CLAY-WORKING INDUSTRIES.

The total value of the clay products in 1911 was $1,947,102, an increase over 1910 of $279,543, or 16.76 per cent. The value of the brick and tile and fire-proof products was $1,918,606, or 98.53 per cent of the total.

By the above increase in value, Alabama rose in rank from 22nd in 1910, to 17th in 1911. In the production of Brick and Tile alone, the State rose in rank from 19th in 1910, to 17th, in 1911. And by an increase of $6250 in the value of Pottery produced the State increased its rank, as in Brick and Tile, from 19th in 1910, to 17th in 1911.

Value of Brick and Tile, and Potteries, 1907-1911.

Product	1907	1908	1909	1910	1911
Brick:					
Common—					
Quantity	159,315,000	120,237,000	146,180,000	135,785,000	129,694,000
Value	$1,004,644	$690,963	$799,693	$746,961	$708,903
Average per M.	$6.31	$5.75	$5.47	$5.50	$5.47
Vitrified—					
Quantity	13,362,000	18,248,000	20,444,000	19,772,000	21,444,000
Value	$183,895	$244,084	$262,376	$236,516	$246,707
Average per M.	$13.76	$13.38	$12.83	$11.96	$11.51
Front—					
Quantity	(a)	(a)	(a)	(a)	9,169,000
Value	(a)	a()	(a)	(a)	$128,403
Average per M.	$13.90	$17.89	$16.19	$15.96	$14.00
Fancy value	(a)	(a)	(a)	---------	(a)
Fire "	$170,711	$122,354	$196,887	$168,672	$193,375
Draintile "	(a)	$2,046	(a)	$3,773	$3,777
Sewer pipe "	(a)	(a)	(a)	(a)	(a)
Fireproofing "	(a)	(a)	(a)	(a)	(a)
Pottery:					
Red earthenware "	$7,530	$15,058	$11,886	$3,475	$11,243
Stoneware and yellow and Rockingham ware value	$20,215	$9,031	$24,453	$16,371	$14,753
Miscellaneous "	$367,414	$476,070	$404,832	$496,791	$639,941
Total value	$1,754,409	$1,559,606	$1,700,127	$1,667,559	$1,947,102
Number of operating firms reporting	100	108	100	87	82
Rank of State	20	19	22	22	17

BRICK AND TILE.

The total number of common brick produced in 1911 was 129,694 thousand (M), a decrease from 1910 of 6,091 thousand, or 4.48 per cent. The value was $708,903, a decrease of $38,058 or 5.09 per cent. The value of vitrified brick produced in 1911 was $246,707, an increase over 1910 of $10,191, or 4,31 per cent. Common brick was the only brick and tile product whose production fell off in 1911. Vitrified brick, front brick, fire brick, drain tile, and miscellaneous ware all show an increase ranging from 0.10 to 28.9 per cent. Below is a table showing the production and values for 1911, and one showing the relation of the quantities produced, and the values, in 1911 to those of 1910.

The decrease in the common-brick output may be partly accounted for by the increased use of hollow block or tile for the construction of large buildings and even of dwelling houses. This form of construction offers many advantages, among which are economy in construction, the ease and rapidity with which it can be put in the wall, and its nonconductivity. All of these should be factors in the extension of its use. Structures made of hollow tile may be faced either with brick, stucco, or other material. It seems, therefore, likely that the production of common brick will not show rapid increase in the future, and it is probable that the use of hollow tile or block will largely increase.

Production of Brick and Tile in 1911.

Kind	Quantity M.	Value	Averag. Value per M.	Percentage of Total Alabama Brick & Tile	Percentage of Total U. S. Value
Common Brick	129,694	$ 708,903	$5.47	36.95	1.42
Vitrified Brick	21,444	246,707	11.50	12.86	2.46
Front Brick	9,169	128,403	14.00	6.69	1.48
Fire Brick	11,929	193,375	16.21	10.08	1.33
Drain Tile	------	3,777	-------------	.20	0.04
Miscellaneous	------	*637,441	-------------	33.22	2.69
Total	------	$1,918,606	-------------	100.00	1.50

*Includes also Fancy Brick, Sewer Pipe, Fireproofing, and Silica Brick.

Production of Brick and Tile in 1910 and 1911.

	1910			1911				
	Quantity M.	Value	Averag. Price	Quantity M.	Value	Averag. Price	Increase or Decrease in Value	Per Cent.
Common Brick	135,785	$ 746,961	$5.50	129,694	$ 708,903	$5.47	—$38,058	— 5.09
Vitrified Brick	19,772	236,516	11.96	21,444	246,707	11.50	+ 10,191	+ 4.31
Front Brick	†	†	----	9,169	128,403	14.00	+ 4	-----
Fire Brick	10,365	163,672	15.75	11,929	193,375	16.21	+ 29,703	+18.14
Drain Tile	------	3,773	----	------	3,777	----	+ 4	+ .10
Miscellaneous	------	494,391	----	------	*637,441	----	+143,050	+28.9
Total	------	$1,645,313	----	------	$1,918,606	----	+273,293	+16.6

*Includes Fancy Brick, Sewer Pipe, Fireproofing and Silica Brick.
†Included in Miscellaneous.

POTTERIES.

Alabama produces pottery of only the commoner or coarser types, red and yellow earthenware, and most of this is produced for local trade only. The product of the 18 active producing firms was valued at $28,496, an increase over 1910, of $6,250, or 28.09 per cent. Below are tables showing the values of the various kinds of the pottery produced in 1911, and also one giving a comparison of the values in 1910 and 1911.

Value of Pottery Products in 1911.

Kind	Value	Percentage of total Alabama Potteries	Percentage of total U. S. value
Red Earthenware	$11,243	39.45+	1.26
Stoneware and Yellow and Rockingham ware	*17,253	60.54+	2.91
Total	$28,496	100.00	0.08

*Includes miscellaneous ware.

Comparison of Pottery in 1910 and 1911.

Kind	1910	1911	Increase or Decrease	Percentage Increase or Decrease
Red Earthenware	$3,475	$11,243	+$7,768	+223.54
Stoneware and Yellow and Rockingham ware	*18,771	*17,253	— 1,518	— 8.07
Total	$22,246	$28,496	+$6,250	+ 28.09

*Includes miscellaneous ware.

COAL.

E. W. PARKER.

PRODUCTION.

TOTAL production in 1911, 15,021,421 short tons; spot value, $19,079,949. From the depressed condition of the iron industry in 1911, it was estimated, in a preliminary review published in the closing week of the year, that the coal production of Alabama had decreased about 10 per cent from the high record of 16,111,462 short tons made in 1910. The quantity of coal made into coke, which is immediately affected by the demands of the iron furnaces, did show the marked decrease of 1,288,111 short tons, or 29 per cent, from 4,417,443 tons in 1910 to 3,129,332 tons in 1911. This decrease was in part made up, however, by an increase of approximately 200,000 tons in the production for other purposes and the total decrease amounted to 1,090,041 short tons, or 6.8 per cent. The decrease in value, somewhat less in proportion, was $1,156,904, or 5.7 per cent, from 20,236,853 to $19,079,949. The average price per ton advanced from $1.26 in 1910 to $1.27 in 1911.

Rank of first ten coal-producing States in 1910 and 1911, with quantity and value of product and percentage of each.

1910.

Production				Value			
Rank	State or Territory	Quantity (short tons).	Percentage of total product'n	Rank	State or Territory	Value	Percentage of total value
1	Pennsylvania:			1	Pennsylvania:		
	Anthracite	84,485,236	16.8		Anthracite	$160,275,302	25.5
	Bituminous	150,521,526	30.0		Bituminous	153,029,510	24.3
2	West Virginia	61,671,019	12.3	2	West Virginia	56,665,061	9.0
3	Illinois	45,900,246	9.1	3	Illinois	52,405,897	8.3
4	Ohio	34,209,668	6.8	4	Ohio	35,932,288	5.7
5	Indiana	18,389,815	3.7	5	Indiana	20,813,659	3.3
6	Alabama	16,111,462	3.2	6	Alabama	20,236,853	3.2
7	Kentucky	14,623,319	2.9	7	Colorado	17,026,934	2.7
8	Colorado	11,973,736	2.4	8	Kentucky	14,405,887	2.3
9	Iowa	7,928,120	1.6	9	Iowa	13,903,913	2.2
10	Wyoming	7,533,088	1.5	10	Wyoming	11 706,187	1.9

1911.

Production				Value			
Rank	State or Territory	Quantity (short tons).	Percentage of total product'n	Rank	State or Territory	Value	Percentage of total value
1	Pennsylvania:			1	Pennsylvania:		
	Anthracite	90,464,067	18.2		Anthracite	$175,189,392	28.0
	Bituminous	144,754,163	29.2		Bituminous	146,347,858	23.4
2	West Virginia	59,831,580	12.1	2	Illinois	59,519,478	9.5
3	Illinois	53,679,118	10.8	3	West Virginia	53,670,515	8.6
4	Ohio	30,759,986	6.2	4	Ohio	31,810,123	5.1
5	Alabama	15,021,421	3.0	5	Alabama	19,079,949	3.0
6	Indiana	14,201,355	2.9	6	Indiana	15,326,808	2.4
7	Kentucky	13,706,839	2.8	7	Colorado	14,747,764	2.4
8	Colorado	10,157,383	2.0	8	Kentucky	13,617,217	2.2
9	Iowa	7,331,648	1.5	9	Iowa	12,663,507	2.0
10	Virginia	6,864,667	1.4	10	Wyoming	10,508,863	1.7

Coal production of Alabama in 1910 and 1911, by counties, in short tons.

1910.

County	Losed at mines for shipment	Sold to local trade and used by employees	Used at mines for steam and heat	Made into coke	Total quantity	Total value	Average price per ton	Average number of days active	Average number of employees
Bibb	1,462,720	6,961	110,883	--------	1,580,564	$2,370,919	$1.50	261	2,666
Etowah	169,251	1,538	1,676	--------	172,465	254,798	1.48	251	388
Jefferson	4,289,536	109,377	329,777	3,570,012	8,298,702	10,247,456	1.23	255	10,832
St. Clair	411,247	2,398	14,764	--------	428,409	571,675	1.33	234	524
Shelby	450,324	3,381	34,436	--------	488,141	780,887	1.60	253	847
Tuscaloosa	412,144	6,842	54,498	607,735	1,081,219	1,232,495	1.14	264	1,496
Walker	3,395,104	66,561	87,118	239,696	3,788,479	4,395,910	1.16	227	4,889
Winston	16,192	250	------	--------	16,442	25,370	1.54	156	57
Other counties*	287,293	8,583	10,855	--------	256,731	356,723	1.39	241	531
Small mines	--------	310	------	--------	310	620	2.00	----	----
Total	10,843,811	206,201	644,007	4,417,443	16,111,462	$20,236,853	$1.26	249	22,230

1911.

County	Losed at mines for shipment	Sold to local trade and used by employees	Used at mines for steam and heat	Made into coke	Total quantity	Total value	Average price per ton	Average number of days active	Average number of employees
Bibb	1,515,976	9,592	107,629	--------	1,633,197	$ 2,407.918	$1.47	239	2,631
Blount	80,266	1,900	100	--------	82,266	98,599	1.20	225	189
Etowah	252,866	720	2,274	--------	255,860	360,307	1.40	189	492
Jefferson	4,804,221	86,017	307,265	2,578,887	7,776,390	9,668,726	1.24	246	10,665
St. Clair	509,120	1,584	18,507	--------	529,211	673,576	1.27	240	682
Shelby	430,505	2,723	29,861	--------	463,089	757,772	1.64	240	866
Tuscaloosa	585,666	9,310	61,624	375,058	1,031,658	1,288,235	1.25	265	1,445
Walker	2,820,521	25,077	82,610	175,387	3,103,595	3,598,720	1.16	180	5,360
Winston	16,074	350	------	--------	16,424	25,185	1.50	67	129
Other counties† & small mines	120,348	3,918	5,465	--------	129,731	200,911	1.55	170	248
Total	11,135,563	141,191	615,335	3,129,332	15,021,421	$19,079,949	$1.27	227	22,707

*Blount, Cullman, DeKalb, Jackson and Marion.

†Cullman, DeKalb, Jackson and Marion.

In the following table is presented a statement of the production of coal in Alabama, by counties, during the last five years, with increases and decreases in 1911 as compared with 1910:

Coal production of Alabama, 1907-1911, by counties, in short tons.

County	1907	1908	1909	1910	1911	Increase (+) or decrease (—), 1911.
Bibb	1,297,158	1,166,548	1,338,243	1,580,564	1,633,197	+ 52,633
Blount						
Cullman	*336,308	*181,062	*186,261	*235,456	*210,070	— 25,386
Etowah	205,015	8,880	46,194	172,465	255,860	+ 83,395
Jefferson	7,526,275	5,914,129	7,176,922	8,298,702	7,776,390	— 522,312
St. Clair	283,806	193,434	354,005	428,409	529,211	+ 100,802
Shelby	245,087	407,547	524,925	488,141	463,089	— 25,052
Tuscaloosa	1,047,364	712,101	1,006,989	1,081,219	1,031,658	— 49,561
Walker	3,254,919	2,941,836	2,973,776	3,788,479	3,103,595	— 684,884
Winston	35,333	28,408	32,278	16,442	16,424	— 18
Other counties and small mines	19,189	50,648	63,857	21,585	1,927	— 19,658
Total	14,250,454	11,604,593	13,708,450	16,111,462	15,021,421	— 1,090,041
Total value	$18,405,468	$14,647,891	$16,306,236	$20,236,853	$19,079,949	—$1,156,904

*Includes production of Marion County.

So far as known, the earliest record of the existence of coal in Alabama was made in 1834. The first statement of production in the State is contained in the United States census report for 1840, in which year the production is given as 946 tons. The census report for 1850 does not mention any coal production for the State, and the next authentic record is contained in the census statistics of 1860, when Alabama is credited with an output of 10,200 short tons. The mines of Alabama were probably worked to a considerable extent during the Civil War, but there are no records of the actual production until 1870, for which year the United States census reports a production of 11,000 tons. Ten years later the production had increased to 323,972 short tons, but the development of the present great industry really began in 1881 and 1882, when attention was directed to the large iron deposits near the city of Birmingham, and thus the great "boom" of that city and vicinity was inaugurated. By 1885 the coal production of the State had increased to nearly 2,500,000 tons. Then followed a period of relapse and liquidation, which lasted two years, after which business settled down to a conservative and rational basis and has since developed steadily. In 1902 the coal production of the State reached a total of more than 10,000,000 tons, and reached the maximum of 16,111,462 tons in 1910.

The statistics of production in Alabama from 1840 to the close of 1911 are shown in the following table:

Production of coal in Alabama from 1840 to 1911, in short tons.

Year	Quantity	Year	Quantity	Year	Quantity	Year	Quantity
1840	946	1859	9,000	1878	224,000	1897	5,893,770
1841	1,000	1860	10,200	1879	280,000	1898	6,535,283
1842	1,000	1861	10,000	1880	323,972	1899	7,593,416
1843	1,200	1862	12,500	1881	420,000	1900	8,394,275
1844	1,200	1863	15,000	1882	896,000	1901	9,099,052
1845	1,500	1864	15,000	1883	1,568,000	1902	10,354,570
1846	1,500	1865	12,000	1884	2,240,000	1903	11,654,324
1847	2,000	1866	12,000	1885	2,492,000	1904	11,262,046
1848	2,000	1867	10,000	1886	1,800,000	1905	11,866,069
1849	2,500	1868	10,000	1887	1,950,000	1906	13,107,963
1850	2,500	1869	10,000	1888	2,900,000	1907	14,250,454
1851	3,000	1870	11,000	1889	3,572,983	1908	11,604,593
1852	3,000	1871	15,000	1890	4,090,409	1909	13,703,450
1853	4,000	1872	16,800	1891	4,759,781	1910	16,111,462
1854	4,500	1873	44,800	1892	5,529,312	1911	15,021,421
1855	6,000	1874	50,400	1893	5,136,935		
1856	6,800	1875	67,200	1894	4,397,178	Total	221,175,236
1857	8,000	1876	112,000	1895	5,693,775		
1858	8,500	1877	196,000	1896	5,748,697		

The number of men employed in the coal mines of Alabama in 1911 was 22,707, who worked an average of 227 days, against 22,230 men, for an average of 249 days in 1910. The more working days in 1910 and the larger production in that year were due to the strike in Illinois and other Western States, and to low water in Ohio and Kanawha rivers, which reduced shipments from Pennsylvania and West Virginia to Mississippi River points. The average production per man in 1911 was 662 tons against 725 tons in 1910. The average daily production per man was 2.92 tons in 1910 and 3 tons in 1911. Most of the Alabama mines are worked 10 hours a day.

Average production per man compared with hours worked per day, and average number of days worked in 1910 and 1911.

Year	8 hours		9 hours		10 hours		All oth'rs	Total	Days Worked	Average Tonnage	
	Mines	Men	Mines	Men	Mines	Men	Men	Men		Per Year	Per Day
1910	18	766	36	2,633	134	17,306	1,525	22,230	249	725	2.91
1911	15	550	50	5,345	102	12,628	4,184	22,707	227	662	2.92

As in 1910, the coal mines of Alabama in 1911 were practically free from labor troubles, there having been only one instance of disaffection reported. In that case 210 men were idle six days. The supply of labor was adequate, and there was no complaint on account of the lack of transportation facilities.

Statistics of Labor Troubles in 1910 and 1911.

Year	Number of Men on Strike	Percentage of total men working	Total days lost	Average number of days lost per man
1910	25	0.11	1,250	50
1911	210	0.92	1,260	6

The returns for 1911 show a decrease of 45 in the number of machines employed, 317 having been reported in 1910 and 272 in 1911.

The production by machines decreased from 2,980,122 tons to 2,936,512 tons. The percentage of the machine-mined product to the total increased, however, from 18.5 in 1910 to 19.6 in 1911. In explanation of the decrease in the number of machines employed in 1911 in the coal mines of Alabama and in the quantity of coal mined by their use, there were 3 mines which reported a total of 27 machines in 1910, which were idle throughout the whole of 1911. Two other properties at which 7 machines were used in 1910 reported no machines used in 1911. One mine which reported 12 pick machines in 1910 used 2 continuous cutters in 1911, and another, which reported 16 machines in 1910, used but 13 in 1911.

Number and kinds of machines in use, and average production per man compared with production by machines, by short tons, in 1910 and 1911.

Year	Pick	Chain Breast	Long-wall	Short-wall	Total	Average Tonnage		Production by Machines	
						Per year	Per day	Total tonnage by machines	% of machined coal to state total
1910	215	82	20	----	317	725	2.91	2,980,122	18.50
1911	184	53	13	22	272	6.62	2.92	2,936,512	19.55
Increase or decr.	— 31	— 29	— 7	----	— 45	— 53	+ .01	— 93,610	
Per cent	—14.41	—35.36	—35.00	----	—14.19	—7.31	-----	— 1.46	-----

The methods used in the mining of coal were reported by mines having a total production in 1911 of 14,233,483 tons, of which 4,673,719 tons were mined by hand, 2,936,512 tons were mined by machines, and 6,623,252 tons were shot from the solid. The mined coal (that is, the coal undercut by machines, added to that mined by hand) represented 53.5 per cent. of the total, and that shot from the solid, 46.5 per cent. Exclusive of the coal mined by machinery, the percentage of coal shot from the solid was 58.6 and that mined by hand was 41.4 per cent.

Quantity and percentage of bituminous coal produced by different methods in 1911.

Mined by hand	Percentage	Shot off the solid	Percentage	Mined by machines	Percentage	Not reported	Percentage	Total production
4,673,719	31.1	6,623,252	44.1	2,936,512	19.6	787,938	5.2	15,021,421

The quantity of Alabama coal washed in 1911, most of which was used in the manufacture of coke, was 6,251,828 short tons, yielding 5,538,401 tons of cleaned coal and 713,427 tons of refuse.

Quantity and percentage of coal washed, by short tons, in 1910 and 1911.

Year	Quantity of coal washed	Percentage of coal mined	Quantity of clean coal	Refuse	
				Quantity	% of total coal washed
1910	6,772,860	42.03	5,971,305	801,555	11.82
1911	6,251,828	41.61	5,538,401	713,427	11.41
Increase or decrease	− 521,032		− 432,904	− 88,128	
Per cent	7.69		7.09	10.99	

According to statistics compiled by the United States Bureau of Mines there were more men killed by explosions, including those from windy shots, in the coal mines of Alabama in 1911 than in any other State, the death roll from this cause in Alabama totaling 130, or more than 30 per cent of all the deaths from this cause. The total number of men killed underground was 204, there being in addition to the 130 deaths from explosion, 47 from falls of roof or coal, 14 from haulage accidents, 5 from explosions of powder, and 8 from other causes. One man was killed by shaft accident and 4 were killed on the surface. The aggregate deaths from accidents above and below ground were 209. The death rate per 1,000 employees was 9.2 and the number of tons mined for each life lost was 71,873.

For a condensed account of the Coal Fields of Alabama, refer to Bulletin 12 of the Geological Survey of Alabama, Statistics of the Mineral Production of Alabama for 1910.

COKE.

E. W. PARKER.

NOTWITHSTANDING the decrease of 487,506 short tons in Alabama's output of coke in 1911 as compared with 1910, the State once more took second place among the coke-producing States, displacing West Virginia, which had held it for six consecutive years. Prior to 1906 the two States were close rivals for that distinction, which alternated almost regularly between them.

Rank of the first five States in production of coke, 1907-1911.

State	1907	1908	1909	1910	1911
Pennsylvania	1	1	1	1	1
Alabama	3	3	3	3	2
West Virginia	2	2	2	2	3
Illinois	10	9	5	4	4
Colorado	5	5	6	6	5

On account of Alabama's remarkable resources in iron ore, limestone, and coal, and her ability to produce pig iron more cheaply than it can be made anywhere else in the world, the State assumes relatively greater importance in years of depression in the iron trade than when demand is brisk and prices high. The former condition obtained in 1911, and although Alabama's production was less than in 1910, the decrease in iron production and in the manufacture of coke was not so great as in some of the other States. West Virginia, whose coke product has no local outlet, but is sent out of the State to market where it has to compete with cokes from other States, showed a decrease in coke output in 1911 amounting to 1,512,801 short tons, and reducing the total of the State to 2,291,049 tons. The production of Alabama decreased from 3,249,027 tons in 1910 to 2,761,521 in 1911, a loss of 487,506 tons, but exceeding the output of West Virginia by a little over 470,000 tons. The value of Alabama's coke production in 1911 was $7,593,594, against $9,165,821 in 1910, a decrease of $1,572,227, or 17.2 per cent.

Comparison of Production and Value of Coke in Alabama in 1910 and 1911.

	No. of Ovens	Coal Charged Short Tons	Coke Produced Short Tons	Total value of coke at ovens	Per cent of total U. S. value
1910	10,132	5,272,322	3,249,027	$9,165,821	9.19
1911	10,121	4,411,298	2,761,521	7,593,594	9.02
Decrease	11	861,024	487,506	1,572,227	
Per cent		16.33	15.00	17.15	

The average price per ton declined from $2.82 to $2.75. The average price for West Virginia coke in 1911 was $1.85 per ton.

Still another comparison may be made between Alabama's coke production and that of West Virginia. It is well known that the average quality of West Virginia's coal exceeds that of Alabama, yet in 1911 the yield of coal in coke in Alabama's operations was 62.6 per cent and in West Virginia 60.4. A part of this difference is undoubtedly due to the fact that in Alabama 340 by-product ovens were in operation in 1911, from which the output amounted to 669,433 short tons of coke, or 24.24 per cent of the total output of the State. In West Virginia there were 120 retort ovens in operation in 1911 and their output was 165,099 short tons of coke, or 7.21 per cent of the total product. The 340 retort ovens in Alabama consisted of 240 Semet-Solvay ovens at Ensley and 40 at Tuscaloosa, which have been in operation for several years and 60 Koppers ovens, completed during 1911 by the Woodward Iron Co., at Woodward. An additional plant of 280 Koppers ovens was under construction at the close of 1911 at Corey for the Tennesee Coal, Iron & Railroad Co. This was the only new construction work in progress at the end of the year. There were 44 establishments in Alabama in 1911—an increase of 1 over 1910. The number of ovens in existence at the close of 1911 was 10,121, a decrease of 11 as compared with 1910, for whereas 60 retort ovens were added to the equipment in 1911, 71 beehive ovens were abandoned. Of the 44 establishments in Alabama in 1911, 14, with a total of 2,474 ovens, were idle throughout the year. In addition to these there were 330 ovens, portions of other establishments, which were idle during the entire year. The number of active ovens was therefore 7,317, and the average production from them in 1911 was 377 short tons, against 9,614 active ovens in 1910, with an average production per oven of 338 tons.

The principal coal beds of Alabama which furnish the coal for coke making are the Pratt, the Mary Lee, and the Blue Creek, all of which are in the Warrior Basin, and the mining operations are in Jefferson, Walker and Tuscaloosa counties. Some coking coal is also produced from the Buck or Blocton No. 1 bed, in Bibb County.

Statistics of the manufacture of coke in Alabama, 1880-1911.

Year	Establishments	Ovens		Coal used (short tons)	Coke produced (short tons)	Total value of coke at ovens	Value of coke at ovens per ton	Yield of coal in coke (per cent.)
		Built	Building					
1880	4	316	100	106,283	60,781	$ 183,063	$3.01	57.0
1890	20	4,805	371	1,809,964	1,072,942	2,589,447	2.41	59.0
1900	30	6,529	690	3,582,547	2,110,837	5,629,428	2.67	58.9
1907	48	9,889	50	4,978,296	3,021,794	9,216,194	3.05	61.0
1908	45	10,103	0	3,875,791	2,362,666	7,169,901	3.04	61.0
1909	43	10,061	0	5,080,764	3,085,824	8,068,267	2.61	60.7
1910	43	10,132	340	5,272,322	3,249,027	9,165,821	2.82	61.6
1911	44	*10,121	†280	4,411,298	2,761,521	7,593,594	2.75	62.6

*Includes 280 Semet-Solvay and 60 Koppers ovens.
†Koppers by-product ovens.

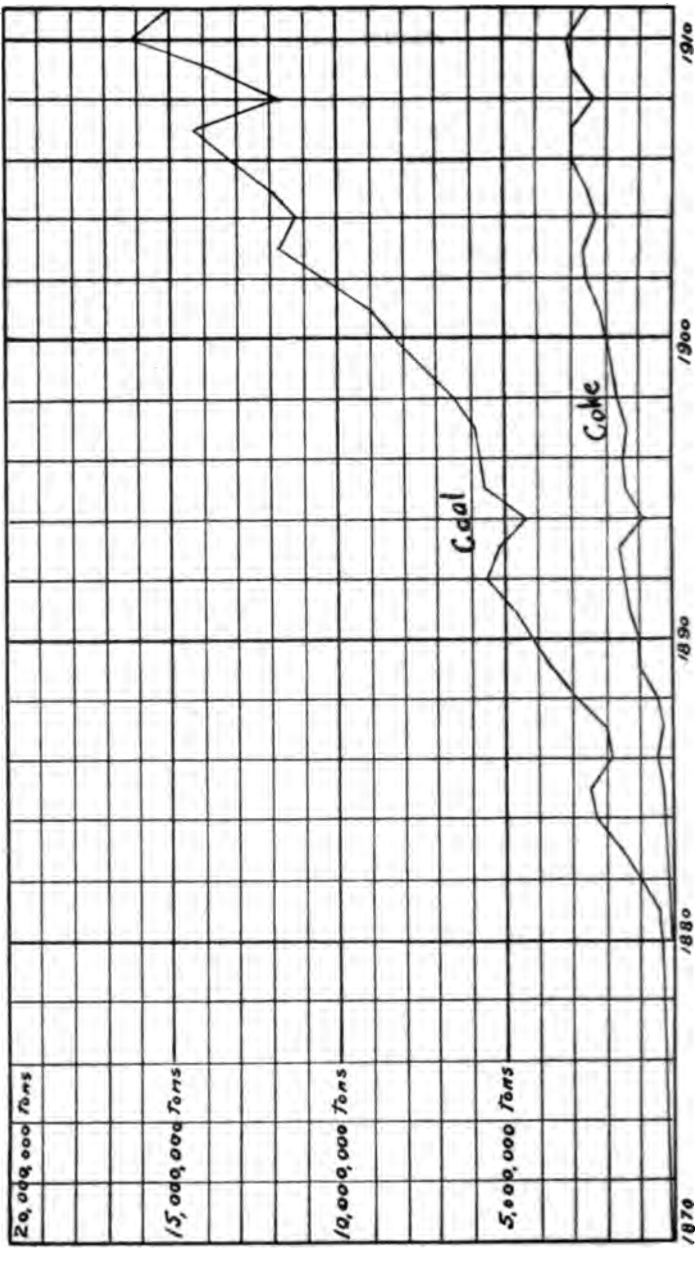
Out of a total of 4,411,298 short tons of coal made into coke in Alabama in 1911, about 55 per cent, or 2,420,117 tons, was washed slack. The washed run-of-mine coal used was a little over one-half the quantity of washed slack, or 1,295,109 tons. The unwashed coal used for coke making in Alabama in 1911 was 693,135 tons of unwashed mine-run and 2,937 tons of unwashed slack. The total quantity of washed coal used was 3,715,226 short tons, or about 84.2 per cent of the total quantity of coal made into coke.

The character of the coal used in the manufacture of coke in Alabama in 1890, 1900, and for the last five years, is shown in the following table:

Character of coal used in the manufacture of coke in Alabama, 1890-1911, in short tons.

Year	Run of mine		Slack		Total
	Unwashed	Washed	Unwashed	Washed	
1890	1,480,669	0	206,106	123,189	1,809,964
1900	1,729,882	152,077	165,418	1,535,170	3,582,547
1907	1,020,907	1,697,918	27,483	2,227,048	4,973,296
1908	548,093	1,457,360	53,218	1,817,120	3,875,791
1909	713,992	2,153,801	0	2,212,971	5,080,764
1910	771,931	1,308,085	0	3,192,306	5,272,822
1911	693,135	1,295,109	2,937	2,420,117	4,411,298

Curves showing the production of Coal and Coke, by tons, in Alabama from 1870 to 1911 inclusive



GOLD AND SILVER.

H. D. M'CASKEY.

THE mine production of gold in Alabama in 1911 was 915-06 fine ounces, valued at $18,916, and of silver, 171 fine ounces, valued at $91, against 1,622.16 fine ounces of gold, valued at $33,533, and 268 fine nounces of silver, valued at $145, in 1910. The value of the output decreased in 1911 therefore by $14,617 in gold and $54 in silver. The silver production is from recovery of this metal in refining the gold. No copper output and no placer production were reported from Alabama in 1911.

The mine production of Alabama in 1911 was from 6,360 short tons of siliceous ore with an average recovered value per ton in gold and silver of $2.99, against 9,763 tons averaging $3.41 in 1910 and 9,886 tons averaging $2.96 in 1909.

The output of 1911 was again mainly from the Hog Mountain mines in Tallapoosa County. The siliceous ores of this mine are in part oxidized and in part sulphides and they are treated in a 120-ton cyanide plant. No operations were reported at the Gold Ridge properties in Randolph County. At the Story prospect a small tonnage was treated in a 5-stamp amalgamation mill. The vein is in oxidized ore and is opened by an adit 150 feet long and a 75-foot shaft. Small trial shipments of gold ore only were made from the Holley prospect near Dadeville in Tallapoosa County.

Gold and Silver production in 1910 and 1911.

	Gold		Silver	
	Quantity oz.	Value	Quantity oz.	Value
1910	1,622.16	$33,533	268	$145
1911	915.06	18,916	171	91
Decrease	707.10	14,617	97	54
Per cent	43.59	43.59	36.19	37.24

GRAPHITE.

E. S. BASTIN.

GRAPHITE is widely distributed among the metamorphic rocks of Alabama, in which it occurs in two forms: (1) In the feebly crystalline schists which have been called Talladega slates, and which in part at least are Paleozoic sediments of as late age as the "Coal Measures," graphite is often found as a graphitic clay free from grit. In this condition the graphite is difficult to separate from the other matter with which it is mixed, and the material has not as yet been utilized to any important extent. Examples of this mode of occurrence may be been near Millerville, in Clay County, and about Blue Hill, in Tallapoosa County. (2) In the mica schists and other highly crystalline rocks, graphite is found in the form of thin crystalline flakes which may be separated from the associated minerals. Graphitic schists of this type are now being worked in three localities, and have in the past been worked at several others.

The more important localities where flake graphite occurs, including the two mines from which the 1911 production was obtained, are described briefly below.

CLAY COUNTY.

The two properties which are at present the leading producers in Alabama are located 4½ and 8 miles west of Ashland. Ashland, the shipping point, is the terminus of a short branch of the Atlanta, Birmingham & Atlantic Railroad. This branch is 7 miles long, and joins the main line at Pyriton. The freight rate on refined graphite from Ashland to New York City is about $7 per ton.

Allen Graphite Co.—The quarry and mill of this company, which was the largest producer in 1910, but which operated only three months in 1911, are located a little over 8 miles west of Ashland, at a settlement shown on the United States Geological Survey's map of the Ashland quadrangle under the name "Graphite." The mine is about one-half mile from the mill, with which it is connected by a tramway. The concentrate is hauled over a fairly good road to Ashland for shipment. The mining is entirely from open pits, and because of the decomposed character of the rock can be accomplished largely with the aid of pick, shovel, and crowbar, without much drilling and blasting. The main pit is about 450 feet in length, 100 feet in average width, and about 60 feet in maximum depth. A small pit just east of the main pit and on the same graphitic band is about 100 feet long, 90 feet wide, and 25 feet deep. A third pit has been opened on the same band of graphitic schist about 1000 feet east of the main pit on the west face of another hill. This is about 90 feet wide, about 200 feet long, and about 40 feet deep. The strike of the schist at the north end of the main pit is N. 80° E., with a dip of 75° S. This is fairly typical for the deposit as a whole.

The rock mined is highly schistose, and is composed largely of quartz and graphite. A white fibrous mineral, probably sillimanite, is also abundant. Feldspar and mica are rare. Few of the thin graphite flakes so far seen by the writer exceed 2 millimeters across, and most of them were under 1½ millimeters. They are arranged subparallel to one another, and to this arrangement and a similar orientation of the sillimanite (?) prisms is largely due the schistosity of the rock. At the west end of the main pit a dike of coarse granite, 1 to 1½ feet wide, parallels the foliation of the schist, and in the easternmost pit the graphitic schist has also been intruded by an irregular body of coarse granite pegmatite carrying muscovite crystals up to 3 inches across. The graphitic beds here are also disturbed by faulting. The contact metamorphic effects of these small intrusions on the graphitic schist appear to be slight.

The milling process is divided into three principal stages: (1) Crushing and drying; (2) preliminary wet concentration; and (3) final dry concentration.

The most important step in the milling process is the preliminary concentration by water flotation. In these concentrators the dry crushed rock is spread in a thin stream upon the surface of slowly flowing water. The graphite being flaky is supported by the surface tension of the water and floats off, while the granular gangue, mainly quartz, sinks and is sent to the dump. The process is cheap where water is plentiful. The tailings seen on the dump carry surprisingly little graphite; that which is present is usually attached to other minerals. Much fine grit of course floats off with the graphite, but is removed in the final dry concentration.

The crude rock is said by the operators to average about 5 per cent graphite. The finished product averages about 2.75 per cent by weight of the crude rock treated. Four principal grades are produced, whose relative proportions are about as follows:

Grades of Flake Graphite Produced by the Allen Graphite Co., Clay County, Ala.

		Per Cent.
Grade C.	**Crucible flake**	**36**
Grade 1.	**Lubricating flake (coarse)**	**11**
Grade 2.	**Lubricating flake (fine)**	**18**
Grade D.	**Dust for foundry facings, etc.**	**35**
		100

The highest grade contains over 90 per cent graphite; the dust averages about 50 per cent graphite. The prevailing average prices f. o. b. New York are: Grade C, 6½ cents per pound; grade 1, 5½ cents per pound; grade 2, 4½ cents per pound; and grade D, 1 cent per pound.

Ashland Graphite Co.—The quarry and mill of this company, which is the successor of the Enitachopco Graphite Co., are located 4½ miles west of Ashland. The product of the plant is hauled by teams to Ashland. The workings of this property consist of two open pits located in the same bed of graphite schist. The two pits are on neighboring knolls, and the mill is in the small valley between them. The largest or eastern pit is about 400 feet long, 30 to 50 feet wide, and 50 feet deep. It follows along the strike of a band of graphitic schist which averages about 30 feet in width, though broadening locally to about 50 feet. The strike is about N. 55° E., and the average dip is about 45° S. E. The second pit, located west of the mill, is about 150 feet long, 20 feet wide, and about 20 feet deep. The trend of the schists is similar to that at the larger pit.

The graphitic rock at this quarry is similar in general to that at the Allen quarry. The schist is too much decomposed for complete identification of all the minerals, but quartz is the principal component. As a rule mica is rare, but the brown mica, biotite, is common in a few places. The graphite forms thin flakes, mostly under 1 millimeter in diameter, although some reach 2 millimeters. No igneous rocks are found in association with the graphitic schist at this property. The rock being more or less decomposed, can be excavated with pick and crow-bar, with occasional blasting. It is loaded into tramcars and hauled to the mill.

The mill has a capacity of about 50 to 60 tons per day of 12 hours. The milling process is in general similar to that at the Allen mill, though differing in details. A dry pan is used in preliminary crushing. The water flotation separators are simliar to those at the Allen plant. The final dry concentration is accomplished by screens and burrstone mills, without the use of Hooper pneumatic concentrators.

CHILTON COUNTY.

Flaketown Graphite Co.—This company operates a quarry and mill in the valley of Chestnut Creek, about 3½ miles northeast of Mountain Creek station. The graphitic rocks lie in the west valley slope, and have been developed by a small open pit. South of this pit sufficient prospecting has been done to show that the deposit is of considerable size. The rock is a graphitic quartz schist very similar to those worked in Clay County. On account of its situation on a steep valley slope, which favors relatively rapid removal of weathered material, the remaining material is not so much decomposed as the deposits west of Ashland, in Clay County.

Small quantities of green micaceous material, probably muscovite, are present in some specimens, but in general, mica is rare. The strike of the schist folia at the main pit is N. 35° W., with a dip of 45° SW. A few hundred yards farther south the strike shifts to N. 20° W. and N. 15° W. A dike of granite pegmatite 1 foot wide intrudes the graphitic schist at the main pit. It parallels the foliation, and within 1 to 2 inches of the schist, carries graphite in scattered flakes up to one-eighth of an inch in diameter.

An analysis made by the United States Geological Survey of a composite sample of graphitic schist, collected from a number of different exposures on this property, showed 4.63 per cent. of graphite. The mill is located at the quarry, and during part of the year electric power for its operation is generated by water power from a 20-foot dam on Chestnut creek. Auxiliary steam power is also installed. Very little material has yet ben marketed, the plant being still in an experimental stage. Mountain Creek is the nearest shipping point.

This plant reported no production in either 1910 or 1911.

COOSA COUNTY.

A graphite deposit is located about 2 miles northwest of Goodwater, a station on the Central of Georgia Railway. At this locality a large number of small prospect pits are scattered over an idea of several acres, and nearly all show graphite quartz schist. The prospects are on a steep southwest hillside overlooking the iron bridge where the wagon road from Goodwater to Pine Grove crosses Hatchet Creek. The rock is gray when fresh, and highly schistose, and strikes nearly east and west, with a dip of about 45° S. It is almost identical in character with the graphitic schist worked in Clay County, and consists largely of quartz and graphite, the latter in flakes mostly under 1 millimeter in diameter. Very little mica is present. An analysis of a composite sample of graphitic schist collected from a large number of pits on this property showed 2 per cent of graphite, but in certain portions the percentage will undoubtedly be greater. The deposit is unquestionably a large one, and its situation on a steep hillside would afford opportunity to work to a considerable depth by open pit methods. The neighboring Hatchet Creek would furnish abundant water for wet concentration of the graphite.

A second deposit, probably of similar character, has been prospected between Mount Olive and Hollins, and is said to be of considerable size.

The foregoing description is from "Mineral Resources of the United States, 1910."

PRODUCTION.

The Alabama production, as usual, was all of the crystalline variety. There was a notable decrease in production as compared with 1910, because the Allen Graphite Co., of Quenelda, only operated for the first three months of the year. The mine and mill of this company were taken over during the year by persons associated with the American Flake Graphite Co., of Pennsylvania, and will be operated under the name of the Quenelda Graphite Co. The Ashland Graphite Co., of Ashland, is also undergoing reorganization and a new mill is in process of erection.

Production of Graphite in 1910 and 1911.

	Quantity Lbs.	Value	Percentage of Total U. S. Quantity	Percentage of Total U. S. Value
1910	1,577,977	$54,688	2.03	14.49
1911	820,000	39,000	1.40	13.51
Decrease	757,977	15,688		
Per cent	48.43	28.67		

IRON ORE.

EUGENE A. SMITH.

IRON ores of Alabama in the order of their economic importance are (1) red ore or hematite; (2) the brown ore or limonite; (3) the gray ore. The black band and clay iron stone have been noticed as occurring in a number of places, but only the red ore and the brown ore have been mined on any large scale.

Practically all the ore mined in Alabama is smelted in the State, the shipments out of the State being about equal to those received from other states.

The tables given below will show the rank of Alabama among the States of the Union both in the production of iron ore and in pig iron, and will show also the quantity of iron produced by charcoal and by coke respectively as fuel.

RED ORE OR HEMATITE.

Practically all the ore of this quality mined in Alabama occurs in the Clinton or Red Mountain formation. The Red Mountain ridges occur on each side of the anticlinal valleys which separate the coal fields. In places the red ore ridges are lacking on one side, usually the western, of the valleys being cut out by faults, while on the other hand the ridge may be duplicated on one side of the valley by the same faults.

In most of the valley occurrences the moderate dips of the ore bed are on the eastern side and there are also practically all of the ore mines. Murphrees Valley makes an exception to this, the moderate dips and the iron mines being on the western side. The iron ore occurs mainly in the central part of the formation in seams or beds one to five in number, which vary in thickness from a few inches to thirty feet.

While the ore seams are very persistent along the outcrop which in Alabama must be as much as 50 miles, yet they vary greatly from place to place, being either too thin or too lean for profitable working in the greater part of this distance.

The most important development of the Clinton ore in this State and in the world is along the 15 or 16 mile stretch of the east Red Mountain between Birmingham and Bessemer, and there is a practically continuous series of mines and strippings for this entire distance. Much mining of this ore has also been done near Gate City, Village Springs, Attalla, Gadsden, Round Mountain, Gaylesville, Ft. Payne, Valley Head, etc.

Production and Value of Hematite in Alabama in 1910 and 1911.

	Quantity Tons	% of total U. S. Prod.	Value	% of total U. S. value
1910	3,678,139	7.12	$4,376,555	3.39
1911	3,119,696	8.43	3,646,925	4.65
Decrease	558,443	-----------	729,630	---------------
Per cent	15.18	-----------	16.67	---------------

The average price per long ton of hematite in Alabama in 1910 was $1.19; in 1911, $1.17.

BROWN ORE OR LIMONITE.

This ore, the second in importance in the State and in the United States, furnished only 4.63 per cent of the total iron ore production of the United States in 1911. Of this Alabama produced 43.96 per cent, 835,886 long tons, and the State holds the *first* rank in this industry.

In the early days of iron making and up to the year 1876 this was the only ore used in the catalan forges, bloomaries, and charcoal furnaces of the State. It was then demonstrated that good iron could be made at low cost from the red ores, with coke for the fuel.

In general the limonites are considered the best of the ores of Alabama and they command the highest prices and command a ready sale.

The usual mode of occurrence is in irregular masses of concretionary origin in the residual clays resulting from the decomposition of limestones, and as a consequence the mining is uncertain and expensive. Limonite also occurs in regularly stratified seams or beds, and then it is the result of the alteration of pyrites or of carbonate ores. Practically all of the brown ore actually mined is that occurring in the residual clays above mentioned. Most of the ore before going to the furnace is washed and screened, and this manipulation, together with the cost of mining, makes it the most expensive of the iron ores, and it is therefore seldom used alone, but is usually mixed with the red ore in proportions determined by the quality of the iron desired. It is used alone in the charcoal furnaces and also in the coke furnaces when a particularly tough pig iron is wanted.

The limonite deposits are very numerous and are distributed over a broad expanse of country and in many places are known to be very extensive. In some of the deposits are ore is in nearly solid mass, in others it is much scattered, and in consequence the amount of foreign material necessary to be moved for every ton of ore produced, varies very much, not only in the different ore banks but also in the different parts of the same bank.

The deposits occur in nearly all the geological formations of the state, but in most of these the ore is either insufficient in quantity or not pure enough to be of much commercial value. The most important of the deposits, in point of extent and value, occur overlying the following formations, viz., the Knox Dolomite and the Weisner Quartzite, the Lauderdale Chert of the Lower Carboniferous, and the Lafayette. Some extensive beds of ore of inferior quality generally, occur also in the Tuscaloosa formation of the Cretaceous, and in the upper part of the Lower Carboniferous and in the Metamorphic rocks.

The average price per long ton of limonite ore in Alabama in 1910 was $1.53; in 1911, $1.47.

Production and Value of Brown Ore in Alabama in 1910 and 1911.

	Quantity	% of total U. S. Prod.	Value	% of total U. S. value
1910	1,123,186	39.15	$1,707,167	35.28
1911	835,886	43.96	1,229,181	39.18
Decrease	287,250		477,086	
Per cent	25.57		27.94	

Production of Iron Ore in Alabama in 9110 and 1911.

	Hematite (Long Tons)	Brown Ore (Long Tons)	Total Quantity	Value	% of total U. S. value
1910	3,678,139	1,123,136	4,801,275	$6,083,722	4.32
1911	3,119,696	835,886	3,955,582	4,876,106	5.64
Decrease	558,443	287,250	845,693	1,207,616	-------
Per cent decrease	15.18	25.57	17.61	19.85	-------

In the following table the first five States in the production of iron ore are arranged according to their rank as producers in 1910 and 1911, with regard to both the quantity and the value of the ore produced:

Rank of iron-ore producing States in 1910 and 1911, with quantity and value of product and percentage of each.

1910.

Rank	State	Production		Rank	State	Value	
		Quantity, in long tons	Percentage of total product'n			Amount	Percentage of total value
1	Minnesota	31,966,769	56.19	1	Minnesota	$78,462,560	55.75
2	Michigan	13,303,906	23.39	2	Michigan	41,393,585	29.41
3	Alabama	4,801,275	8.44	3	Alabama	6,083,722	4.32
4	New York	1,287,209	2.26	4	New York	3,848,683	2.74
5	Wisconsin	1,149,551	2.02	5	Wisconsin	3,610,349	2.57

1911.

ORE MARKETED.

1	Minnesota	23,398,406	57.08	1	Minnesota	$48,447,760	56.06
2	Michigan	8,944,393	21.82	2	Michigan	23,808,935	27.55
3	Alabama	3,955,582	9.65	3	Alabama	4,876,106	5.64
4	New York	1,057,984	2.58	4	New York	2,959,009	3.42
5	Virginia	610,871	1.49	5	Wisconsin	1,386,616	1.60

Kinds of Ore Produced in Alabama, and Values of same in 1910 and 1911.

	Hematite				Brown Ore				Total		Per cent of U. S. total	
	Quantity (Long Tons)	% of total State Prod.	Value	% of total State value	Quantity (Long Tons)	% of total State Prod.	Value	% of total State value	Quantity (Long Tons)	Value	Quantity	Value
1910	3678139	76.6	$4376555	71.93	1123136	23.39	$1707167	28.07	4801275	$6083722	8.43	4.32
1911	3119696	78.86	3646925	74.79	835886	21.14	1229181	25.21	3955582	4876106	9.65	5.64
Decr's.	558443	----	729630	----	287250	----	477086	----	845693	1207616	---	---
Per ct.	15.18	----	16.67	----	25.57	----	27.94	----	17.61	19.85	---	---

Iron-ore mines of Alabama that produced more than 50,000 long tons each in 1911.

Rank	Name of Mine	Nearest Town	Variety of Ore	Quantity
1	Wooward	Woodward	Hematite	502,471
2	Raimund, No. 1	Bessemer	Hematite	178,793
3	Songo	Birmingham	Hematite	161,912
4	Raimund, No. 2	Bessemer	Hematite	131,314
5	Ironaton	Ironaton	Brown Ore	114,360
6	Clinton	Steinman	Hematite	111,374
7	Crudup	Gadsden	Hematite	99,486
8	Raimund, No. 3	Bessemer	Hematite	84,775
9	Woodstock	Woodstock	Brown Ore	83,362
10	Etowah	Gadsden	Hematite	68,133
11	Attalla	Attalla	Hematite	65,372
	Total (11 mines)			1,601,352
	Unspecified* (6 mines)			1,890,209
	Total of mines (23) producing less than 50,000 tons			464,021
	Grand total			3,955,582

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*Includes the product of 6 mines producing over 50,000 tons each, operated by 2 companies, which do not permit the publication of individual statistics.

PIG IRON AND STEEL.

THE following table gives the quantity and approximate value of the pig iron produced in the five states leading in the production of pig iron, and shows the increase or decrease, both by totals and by percentages, for 1910 and 1911.

Quantity and value of pig iron produced in the United States in 1910 and 1911, by States, in long tons.

State	1910		1911		Decrease in 1911		Perc'tage of decrease in 1911	
	Quantity	Value (Dollars)	Quantity	Value (Dollars)	Quantity	Value (Dollars)	Quantity	Value
Pennsylvania	11,014,652	174,486,833	9,581,109	136,328,507	1,433,543	38,158,326	13.01	21.87
Ohio	5,584,279	85,385,254	5,371,378	73,484,592	212,901	11,900,662	3.81	13.94
Illinois	2,606,335	41,465,543	2,036,081	31,152,927	570,254	10,312,616	21.88	24.87
Alabama	1,969,770	24,127,616	1,617,150	17,379,171	352,620	6,748,445	17.90	27.97
New York	1,895,018	31,693,623	1,537,201	23,924,194	357,817	7,769,429	18.88	24.51

The figures above given are from the U. S. Geological Survey.

The following tables have been furnished by Mr. J. M. Swank of the American Iron and Steel Association, and Mr. Wm. G. Gray of the Bureau of Statistics of the American Iron and Steel Institute. The difference in the statistics for 1910 and 1911, are due to the fact that the figures of the U. S. Geological Survey represent shipments while the others represent the actual production.

Production of pig iron in Alabama, 1907-1912.

J. M. Swank and Wm. G. Gray.

Year	Coke Pig Iron Long Tons	Charcoal Pig Iron Long Tons	Total Long Tons
1907	1,651,583	35,141	1,686,725
1908	1,873,199	23,815	1,397,014
1909	1,729,976	33,641	1,763,617
1910	1,903,443	35,704	1,939,147
1911	1,679,654	32,557	1,712,211
1912	1,828,648	34,033	1,862,681

Alabama Production of Rolled Iron and Steel (including Rolled Forging Blooms and Rolled Forging Billets) from 1907 to 1911, inclusive.

J. M. Swank and Wm. G. Gray.

Year	Iron	Steel	Total
1907	44,728	238,569	283,297
1908	4,417	269,235	273,652
1909	1,267	256,705	257,972
1910	6,419	420,052	426,471
1911	3,550	353,059	356,609

LIME.

C. A. ABELE.

THE total production of thirteen operators in 1911 was 76,406 short tons, a decrease from 1910 of 5290 short tons, or 6.47 per cent. The value of the product was $300,787, a decrease of $2,825, or 0.93 per cent.

Below is a table giving the production and value of lime in 1910 and 1911, and a comparison of these years.

Production of Lime in 1910 and 1911.

	Number of Operators	Quantity Short Tons	Rank of State by quantity	Value	Rank of State by value	Average price per ton	Percentage of total U. S value
1910	14	816,96	15	$308,612	18	$8,72	2.19
1911	13	76,406	15	300,787	16	8.94	2.19
Decrease	------	5,290	------	2,825	------	------	------
Percentage decrease	------	6.47	------	0.98	------	------	------

The most important use of the lime produced, as in 1910 was for building purposes, nearly 60 per cent of the total product being used for this purpose, the remainder being used in chemical plants, sugar refineries, tanneries, for fertilizer, or was distributed through dealers.

Shelby County was the largest producer, having produced 49,256 tons, or 64.46 per cent of the total. The other producers in the order of their rank were Etowah, Blount, Jackson, Calhoun and Colbert counties.

Below is an outline of some of the chemical processes in which lime may be used:

Chemical uses of lime.

E. F. Burchard.

- Agricultural industry:
    - As a soil amendment, c, m.*
    - As an insecticide, c, m.
    - As a fungicide, c, m.
- Bleaching industry:
    - Manufacture of bleaching powder, "Chloride of lime," c.
    - Bleaching and renovating of rags, jute, ramie, and various paper stocks, c, m.
- Caustic alkali industry:
    - Manufacture of soda, potash, and ammonia, c.
- Chemical industries:
    - Manufacture of ammonia, c.
    - Manufacture of calcium carbide, calcium cyanimid, and calcium nitrate, c.
    - Manufacture of potassium dichromate and sodium dichromate, c.
    - Manufacture of fertilizers, c, m.
    - Manufacture of magnesia, m.
    - Manufacture of acetate of lime, c.
    - Manufacture of wood alcohol, c.
    - Manufacture of bone ash, c, m.
    - Manufacture of calcium carbides, c.
    - Manufacture of calcium-light pencils, c.
    - In refining mercury, c.
    - In dehydrating alcohol, c.
    - In distillation of wood, c.
- Gas manufacture:
    - Purification of coal gas and water gas, c, m.
- Glass manufacture:
    - Most varieties of glass and glazes, c.
- Milling industry:
    - Clarifying grain, c, m.
- Miscellaneous manufactures:
    - Rubber, c, m.
    - Glue, c, m.
    - Pottery and porcelain, c, m.
    - Dyeing fabrics, c, m.
    - Polishing material, c, m.
- Oil, fat, and soap manufacture:
    - Manufacture of soap, c.
    - Manufacture of glycerine, c.
    - Manufacture of candles, c.
    - Renovating fats, grease, tallow, butter, c, m.
    - Removing the acidity of oils and petroleum, c, m.
    - Lubricating greases, c, m.
- Paint and varnish manufacture:
    - Cold-water paint, c, m.
    - Refining linseed oil, c, m.
    - Manufacture of linoleum, c, m.
    - Manufacture of varnish, c, m.
- Paper industry:
    - Soda method, c.
    - Sulphite method, m.
    - For strawboard, c, m.
    - As a filler, c, m.
- Preserving industry:
    - Preserving eggs, c.
- Sanitation:
    - As a disinfectant and deodorizer, c.
    - Purification of water for cities, c.
    - Purification of sewage, c.
- Smelting industry:
    - Reduction of iron ores, c, m.
- Sugar manufacture:
    - Beet root, c.
    - Molasses, c.
- Tanning industry:
    - Tanning cowhides, c.
    - Tanning goat and kid hides, c, m.
- Water softening and purifying, c.

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*High calcium lime is indicated by "c," magnesian and dolomitic lime by "m."

MICA.

BY DOUGLAS B. STERRETT.

THE most prominent feature of the minerals of the mica group is their perfect cleavage into tough, flexible, and elastic sheets. The ready cleavage combined with transparency and nonconductivity of electricity render mica valuable in the industrial world. The commercial demand has practically been supplied by two varieties, muscovite and phlogopite, but a small quantity of biotite has been used. Only muscovite and phlogopite have been found in masses of sufficient size and abundance to meet the demands of the trade.

Muscovite, called "white mica," is a silicate of aluminum and potassium containing water; phlogopite, called "amber mica," is a silicate of magnesium, aluminum, and potassium; biotite is a silicate of magnesium, iron, aluminum, and potassium. Phlogophite and biotite may be placed at opposite ends of a chemical series and may grade into each other by variations in the percentage of iron present. In thin sheets muscovite is nearly colorless, phlogopite generally yellow or brownish, and biotite dark brown to black. In sheets of one-sixteenth of an inch or more in thickness muscovite may be colorless, white, gray, yellow inclining to amber, red, brown, or green; phlogopite may be yellow, brown, or black, and sometimes coppery; and biotite is black. Muscovite of a reddish color is often called "rum" and "ruby" mica. The luster of muscovite is brilliant and glimmering on fresh surfaces, and that of phlogophite is less brilliant and more silvery or pearly.

USES.

Mica has a wide commercial application, both in the form of sheet mica and of ground mica. The most extensive use of sheet mica is in the manufacture of electrical apparatus, but a considerable quantity is still used in the glazing trade for stoves, for gas-lamp chimneys, for lamp shades, etc. The demand for mica for glazing is small and only the best quality and the larger sheets are thus used. Both large and small sheet mica is used in the electrical industry. "Micanite," or built-up mica board, for the manufacture of which small-sheet mica can be used, is substituted for large-sheet mica in much electrical work. Mica serves as a perfect insulator in various parts of dynamos, motors, induction apparatus, switchboards, lamp sockets, and nearly every variety of electrical appliance.

The domestic or muscovite mica is satisfactory for all insulation except for commutators of direct-current motors and dynamos built up of bars of copper and strips of mica. For this purpose no mica is as satisfactory as the phlogophite or "amber mica." This mica is of about the same hardness as the copper of the commutator segments and therefore wears down evenly without causing the machine to spark.

A large quantity of scrap mica—small sheets and the waste from the manufacture of sheet mica—is ground for different uses. Among these are the decoration of wall paper and the manufacture of lubricants, fancy paints, and molded mica for electrical insulation. Ground mica applied to wall papers gives them a silvery luster. When mixed with grease or oils finely ground mica forms an excellent lubricant for axles and other bearings. Mixed with shellac or special compositions ground mica is molded with desired forms and is used in insulators for trolley wires. Ground mica for electrical insulation must be free from metallic minerals. Mica used for lubrication should be free from gritty matter. For wall paper and brocade paints a ground mica with a high luster is required, and such luster is best obtained by using a clean light-colored mica and grinding it under water. Coarsely ground or "bran" mica is used to coat the surface of composition roofing material to prevent the tar or other composition used in its manufacture from sticking when the material is rolled for shipping.

From The Mineral Resources of Alabama, 1904, by Eugene A. Smith and Henry McCalley.

"While mica has not been sent from Alabama to the market in anything more than an experimental way, yet there is much reason for thinking that a good mercantile article can be obtained at a number of points in Chilton, Coosa, Clay and Randolph counties. In a belt of mica schists extending through these counties, there are frequent veins of a coarse grained granite or pegmatite, in which the constituent minerals, quartz, feldspar, and mica are segregated in large masses. The feldspar is very generally weathered into kaolin, and it is from these occurrences that we get all the true or vein kaolin. The mica in its turn is present in the form generally of large rough masses or boulders, from which it may be split out in sheets of varying size. In all this belt there are ancient pits or mines in which trees are now growing with a diameter of 18 inches.

Around the mouths of these old diggings are great piles of broken-up refuse mica, apparently showing that a large amount of the mineral had been taken from them. In North Carolina, and probably elsewhere, the old mines of this kind have often proven to be the best places for obtaining good mica in modern times, and this fact may serve as a hint to those who contemplate mica mining in this State.

Most work in getting mica has probably been done near Micaville, in Cleburne county, and at the Pinetucky mine, in Randolph. Many tons of mica, some of it in large sheets six to ten inches in size, have been gotten up and stored away in a house, which was destroyed by fire and the mica injured, so that it has never been sent to market. None of the localities is near a railroad. A little testing, (it can hardly be called mining) has also been done in several places in Clay County, and also in Coosa and Chilton."

PRODUCTION.

There was only one producer of mica operating in 1911, and as this mine was opened only in the latter part of the year, the production was rather light, reaching only 65,000 pounds.

MINERAL WATERS.

G. C. MATSON.

ACCORDING to the returns received from spring owners, the mineral-water trade of Alabama continued to prosper during 1911, sales increasing from 133,159 gallons reported during 1910 to 205,854 gallons in 1911, an increase of 72,695 gallons, or 54.59 per cent. The value, however, owing to a decline of 10 cents per gallon in the average price for the year, decreased 11.94 per cent, or from $30,639 in 1910 to $26,982 in 1911. No new springs were reported during 1911. Two springs which failed to report in 1910 reported in 1911, and one spring reporting in 1910 was idle in 1911; hence, the total number of springs increased from 9 to 10. About three-fourths of the total sales of mineral water in Alabama is used medicinally. There are resorts at 6 of the springs, accommodating more than 700 people, and the water at 2 is said to be used for bathing purposes. In addition to the quantity reported as sold, there were 5,000 gallons used for the manufacture of soft drinks.

The following 10 springs reported sales:

Bailey Springs, Florence, Lauderdale County.
*Bladon Springs, Bladon Springs, Choctaw County.
Blount Springs, Blount Springs, Blount County.
Bromberg Gulf Coast Lithia Springs, Bayou La Batre, Mobile County.
Cherokee Spring, near Citronelle, Mobile County.
Healing Springs, Healing Springs, Washington County.
Ingram Lithia Wells, near Ohatchee, Calhoun County.
Livingston Mineral Springs, Livingston, Sumter County.
Luverne Mineral Springs, Luverne, Crenshaw County.
MacGregor Springs, Spring Hill, Mobile County.
Matchless Mineral Wells, east of Greenville, Butler County.

The following table shows the relative productions, and their respective values, for 1910 and 1911.

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*The Bladon Water Co. sold mineral water from these springs in 1911, and for some years previous to this, but figures showing quantity and value of the water were not available.

Production of Mineral Waters in 1910 and 1911.

	Number of Springs	Quantity Sold	Average Retail price	Value of Medicinal Waters	Value of Table Waters	Total value of Mineral Waters	Percentage of total U. S. value
1910	9	133,159	$0.23	$23,179	$7,460	$30,639	0.48
1911	10	205,854	0.15	20,244	6,738	26,982	0.39
Increase or decrease	+ 1	+ 726.95	− 0.08	− 2,935	− 722	− 3,657	------
Per cent	----	+ 54.59	− 34.68	− 12.66	− 9.69	− 11.93	------

In the latter part of 1912 a number of owners of local mineral springs, whose production is small, and having only a limited distribution, signified a willingness to report their sales, which will probably materially increase Alabama's output in the future.

SAND AND GRAVEL.

C. A. ABELE.

THE total production of sand and gravel in the State in 1911 was 677,894 short tons, valued at $215,413, as compared with 619,253 short tons, valued at $187,291 in 1910, a net increase in quantity of 58,641 short tons, or 9.47 per cent, and an increase of $27,822, or 14.83 per cent in value.

The following tables give the production, value, and disposition of the sand and gravel produced in 1910 and 1911, and a comparison of these years.

Production and Value of Sand in 1910 and 1911.

	Molding Sand		Building Sand		Paving Sand		Furnace Sand		Other Sands		Tota	
	Quantity Tons	Value	Quantity Tons	Value	Quantity Tons	Value	Quantity Tons	Value	Quantity Tons	Value	Quantity Tons	Valu
1910	56085	$22069	228797	$73567	-----	- ----	286	$148	22547	$4477	307715	$1
1911	52766	19432	201214	70284	10975	$ 3635	36540	7738	14988	7391	356293	11
Increase or Decr.	– 3319	– 2637	– 27583	– 3283	-----	- ----	+36254	+7590	– 7559	+ 2914	+ 48578	+ 1
Per cent	– 5.91	–11.95	– 12.05	– 4.46	-----	------	-------	------	–33.52	+65.08	+ 15.78	+

Production of Sand and Gravel in 1910 and 1911.

	Sand		Gravel		Total		Percentage of total U. S. value
	Quant'y	Value	Quant'y	Value	Quant'y	Value	
1910	307,715	$100,261	311,538	$87,330	619,258	$187,591	0.89
1911	356,293	119,758	321,601	95,655	677,894	215,418	1.018
Increase	48,578	19,497	10,063	8,325	58,641	27,822	--------
Per cent	15.78	19.44	3.23	9.53	9.47	14.83	--------

STONE.

E. F. BURCHARD.

THE figures presented in the following report have to do with the stone produced and sold by the quarrymen and include only such manufactured product as is put on the market by the quarrymen themselves. This applies especially to rough and dressed building stone, dressed monumental stone, crushed stone, flagstone, curbstone, and paving blocks. The value given to this manufactured product is the price received by the producer, free on board at point of shipment, and includes therefore the cost of labor necessary to dress the stone. The stone reported as sold rough includes stone sold as rough stock to monumental works, and to cut-stone contractors for building purposes; stone sold as riprap, rubble, and flux; and includes the value of only such labor as is required to get the stone out of the quarry in the shape required by the purchaser. The value given to this stone is the price received by the quarryman free on board at point of shipment. In case the stone is sold to local trade the value is given as the quarryman sells the material, generally at the quarry, but in some cases delivered, if this is done by the producer. In some instances a long haul to market or to the railroad increases the cost of the material, and therefore of the selling price.

PRODUCTION.

C. A. ABELE.

Alabama produces commercially only three kinds of stone, namely, limestone, sandstone, and marble. The most important use of the limestone is blast furnace flux, roadmaking, building and crushed stone for concrete following in the order of their importance. No sandstone for building purposes was reported in 1911, the principal use of this stone being found in the manufacture of concrete, and on dam construction on the Coosa and Tallapoosa Rivers. The value of the marble produced may not be divulged, as there was only one producer in 1911 as in 1910.

Below is a table giving the value of the limestone and sandstone producer in the past five years, from 1907 to 1911.

Value of Stone Production from 1907 to 1911.

Kind	1907	1908	1909	1910	1911
Limestone	$694,699	$479,730	$700,642	$714,516	$561,798
Sandstone	48,673	34,099	77,327	109,063	73,195

LIMESTONE.

The value of the limestone burned into lime, or used in the manufacture of Portland cement, is not taken into account under this heading, but is included in the value of each of the finished products in whose manufacture it is used.

As thus limited, the total value of limestone produced in 1911 was $561,748, as compared with $714,516 in 1910, a decrease of $152,718, or 21.09 per cent.

The values of the limestone producer during the last five years are given below for comparison.

Production of Limestone from 1907 to 1911.

1907	1908	1909	1910	1911
$694,699	$479,730	$700,642	$714,516	$561,798

The values of limestone produced in 1910 and 1911, classified according to the uses of the stone, are given in the following table:

Value of Limestone produced in 1910-1911.

	1910	1911	Increase or Decrease	Per cent.
Rough Building	$1,901	$2,115	+ $214	+ 11.25
Dressed Building	34,001	29,652	— 4,349	— 12.79
Paving	4,500	170	— 4,330	98.00
Curbing	-------	150	----------	-----------
Riprap	37,505	10,459	— 27,046	— 72.11
Road Making	64,872	37,511	— 27,361	— 42.17
Railroad Ballast	5,842	-------	----------	-----------
Concrete	16,199	23,077	+ 6,878	+ 42.46
Flux	545,988	458,356	— 87,632	— 16.05
Other	3,708	308	— 3,400	— 91.69
Total	$714,516	$561,798	— $152,718	— 21.09
Percentage of total U. S. value	2.62	1.66	----------	-----------

LIMESTONE FOR BUILDING PURPOSES.

EUGENE A. SMITH.

From the tables above it will be seen that by far the largest part of the limestone for other purposes than lime burning produced in Alabama 1910-1911, has been for flux rock in the iron furnaces. Crushed stone for road making and riprap follow next, and then dressed building stone.

The preparation of cut stone for building purposes in Alabama, while on the increase, is not yet what it should be. Practically all of this material comes from the quarries in the Subcarboniferous limestone of the Tennessee Valley, the most important quarries being at Rockwood in Franklin County, operated by Foster-Freighton-Gould Co., of Nashville. This stone is quite similar in appearance, composition, and other qualities to the Indiana stone, and so far as experience in the use of the stone from the two localities in the buildings of the University of Alabama goes, the Alabama stone holds its own under influence of the weather better than does the Indiana stone. Stone steps, door sills, and window sills, buttress caps, etc., of the Alabama stone put in place in 1885 show practically no deterioration in color and wear under foot, and in crumbling and roughening under the influence of the weather, which can not be said of some portions of the Indiana stone used in buildings erected in 1909-10. The Rockwood quarries have most modern and approved methods of machinery for sawing the stone and handling it in transit to the mills and elsewhere. The stone is of massive formation, of great thickness and extent. Blocks weighing as much as 25 tons, without crack or flaw, are not infrequently quarried, the size of the blocks being practically limited only by the capacity of the hoisting machinery.

The Oolitic variety is most extensively used for building and monumental work. It is of light gray color, uniform grain, and homogeneous texture. It possesses a quality of cheapness, it can be cut to any design required, and is at the same time strong and durable.

At the present time the business at this quarry is confined to the furnishing of rough and sawed stone to the cut stone contractor or dealer.

With the installing of adequate machinery at the quarry for doing the finished work, there should never be any longer any reason for going outside of the State for this quality of stone. Already the material has been very extensively used in public buildings in Mississippi, Tennessee, as well as in Alabama. The only reason why it was not used in the recently erected buildings at the University of Alabama was that at the time these building contracts were let, the quarries furnished only the rough sawn stone and there was not in Alabama any establishment adequately equipped for the dressing of the stone in the quantity needed.

MARBLE.

EUGENE A. SMITH.

The marble of Alabama is of two kinds, crystalline or true marble and non-crystalline.

The crystalline or statuary marble occurs mainly in a narrow valley along the western border of the metamorphic area, extending from Marble Valley in Coosa County, through Talladega into Calhoun. The length of the marble belt through Coosa and Talladega counties is about 50 miles. The width of the valley carrying the marble as a rule is from one quarter to one half mile, widening in places to a mile and a quarter, for example in the neighborhood of Sylacauga.

The quarries longest known are Gantt's and Herd's near Sylacauga, Nix's near Sycamore, and Taylor's and McKenzie's near Taylor's Mill East of Talladega. From all these marble was quarried before the civil war.

During1911 only 2 establishments had reported any marble production, viz: The Alabama Marble Co., at Gantt's Quarry near Sylacauga and the Alabama-Carara Marble Co. near Talladega. Several other companies, however, have made some rather extensive developments and will no doubt report some production in 1912 and later. These are the Eureka Marble Co. (Bishop's) near Talladega Springs; the Morretti-Harrah Marble Co., Sylacauga; and the Alabama Marble Quarries of the Scott Brothers near Sycamore.

The plant of the Alabama Marble Company at Gantt's Quarry was destroyed by fire in December, 1910, and it was not until the middle of August, 1911, that the rebuilding was completed and production begun. From that time till the end of the year the production was as stated below:

Blocks	17781 Cu. ft.
Unfinished sawed stock	7928 Cu. ft.
Finished stock of all kinds	47639 Cu. ft.
Total finished stock	73348 Cu. ft.
Scrap and broken stone	1457 tons

The cubic feet above stated are, in all cases, the net measure of the quantities sold, with all waste in quarrying, sawing, and finishing eliminated.

I think it is fairly safe to say that on the whole the marble from this quarry and immediate vicinity is of the highest grade of commercial white marble now on the market and obtainable in large quantity. There are small quantities of marble produced both in Italy and Vermont that are somewhat freer from coloring matter than the best grades that can be produced in Alabama in any quantity. But on the other hand, the poorest grades in Alabama greatly surpass the poorest grades produced elsewhere, so that the average of the Alabama deposit is probably somewhat higher than that of any other so far developed, not excluding even the marble from the Carara district in Italy. The marble from this State (Gantt's Quarry) has now a well established reputation and has been used in more than 150 important buildings throughout the United States.

It can be seen in the galleries of the National Museum in Washington.

A beautiful quality of variegated limestone or marble—red, pink and white—belonging probably to the Cambrian formation, occurs in Shelby County a mile or two south of Shelby Springs station on the L. & N. railroad, and extending thence southwest for a mile or two. Nothing but prospecting work has been done on this marble. The Trenton limestone in the Appalachian valleys, particularly Jones Valley below Bessemer, contains marble similar to that quarried in the vicinity of Knoxville, Tenn. Also at Pratt's ferry on the Cahaba River in Bibb County a quarry was for many years worked in this formation and turned out a very beautiful quality of marble varying in color from gray through pink, red, and brown shades.

A black marble which is exceedingly promising, has been reported and some development work done near Anniston, Calhoun County, and some very handsome specimens of cave onyx have been obtained from near Kymulga in Talladega County.

In the Coastal Plain the St. Stephens limestone of the Tertiary holds ledges of hard, almost crystalline rock capable of taking good polish. The colors vary from nearly white, through shades of yellowish into red, and it would make a handsome decorative marble, especially for inside work.

Other limestone formations, such as the Subcarboniferous and the Knox Dolomite, could in places be drawn upon for marble.

SANDSTONE.

The value and distribution of the sandstone produced in 1911, with a comparison of 1910 and 1911, is given in the table below:

Value and Uses of Sandstone Produced in 1910 and 1911.

	Rough Building	Ganister	Rubble	Riprap	Crushed Stone for Concrete	Total	% of total U. S. value
1911	----	12,700	14,362	16,133	30,000	73,195	.94
1910	$100	$12,088	$20,802	$20,073	$56,000	$100,063	1.37
Increase or decrease	----	+ 612	− 6,440	− 3,940	− 26,000	− 53,868	----
Per cent	----	+ 5.06	− 30.96	− 14.64	− 46.42	− 32.88	----

SUMMARY OF THE MINERAL PRODUCTION OF ALABAMA IN 1911.

ON account of the different units of measurement employed in the mineral industry, a summation of the production of the year can include only values of the products. It is also to be noticed that a simple summation of all the values of the minerals, or mineral products listed in this pamphlet would give a value somewhat in excess of the true value, since in many cases, as for instance, coal and coke, the second product is directly a product of the first. To give the values of both as a part of the total would be to repeat, in a measure, a partial value of the first or raw product, and would give an erroneous result.

According to this manner of summation, 1907 was the first and only year in which the value of the Alabama production reached or passed the $50,000,000 mark. The result of the financial depression of 1907 is apparent in the decrease in value of the mineral products of 1908, which declined $17,125,941, or approximately 32 per cent from the 1907 value. In 1909 and 1910 the general recovery in business increased the total values to $41,982,208, and $47,751,109 respectively. In 1911 the decline in pig iron and the decreased coal production brought the total value of the year down to $40,203,712, a decrease of $7,547,397, or 15.6 per cent.

In 1911 coal took the lead as the most valuable product, the others being, in the order of the value, pig iron, brick and tile, limestone, cement, sand and gravel, sandstone, bauxite, pottery, and miscellaneous, including marble, graphite, gold and silver, mica, natural gas, and abrasives.

The following table shows how the total value of the mineral products of the state varied during the last five years:

The total value of the Mineral Products of Alabama from 1907 to 1911.

Year	Value	% of total U. S. value
1907	$52,136,749	2.51
1908	35,010,808	2.19
1909	41,982,208	2.22
1910	47,751,109	2.39
1911	40,203,712	2.09

PROBABLE FUTURE PRODUCTION.

THE following minerals have been produced in Alabama in past years, but no production was reported for 1911: Fullers Earth, Manganese ore, Ocher, Pyrite. Since all these occur in quantity and of quality to make them of commercial value, the production may be resumed at any time.

Among the probable productions in the near future, are natural gas and petroleum, onyx marble, turquoise and other minerals noticed in the Index to the Mineral Resources of Alabama a publication of the State Geological Survey.

Natural gas under pressure of 630 pounds has been obtained from several wells in Fayette and Walker Counties, and smaller quantities under less pressure have been obtained near Huntsville and elsewhere.

A Report with map on the Fayette County Gas Field has been published by the survey during the year. No commercial production has yet been reported.

GEOLOGICAL SURVEY OF ALABAMA

EUGENE ALLEN SMITH, *State Geologist*

BULLETIN No. 14

STATISTICS OF THE MINERAL PRODUCTION OF ALABAMA FOR 1912

COMPILED FROM MINERAL RESOURCES OF THE
UNITED STATES

By
CHARLES ARTHUR ABELE

UNIVERSITY, ALABAMA
1913

PRESS
BROWN PRINTING CO.
MONTGOMERY
ALABAMA

LETTER OF TRANSMITTAL.

UNIVERSITY, ALA., November, 1913.

HON. EMMET O'NEAL,
Governor of Alabama,
Montgomery, Ala.

SIR:—I have the honor to transmit herewith the manuscript of a Report on the Mineral Production of Alabama for the year 1912, with the request that it be printed as Bulletin No. 14 of the Geological Survey of Alabama.

Very respectfully,
EUGENE A. SMITH,
State Geologist.

GEOLOGICAL CORPS.

Eugene Allen Smith, Ph. D.	State Geologist
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Robert S. Hodges	Chemist
Herbert H. Smith	Curator of Museum
Roland M. Harper, Ph. D.	Botanist
George N. Brewer	Field Assistant
C. A. Abele	In Charge of Mineral Statistics
A. T. Donoho	Stenographer.

RIVER GAGE HEIGHT OBSERVERS.

C. J. Stowe	Jackson's Gap, Tallapoosa River
J. E. Whitehead	Riverside, Coosa River
S. T. Dillard	Beck, Conecuh River
Ed. Bullin	Red Bay, Big Bear Creek
E. Cummings	Wedowee, Little Tallapoosa River

From the records of daily observations of the gage readings at these places when extended through sufficient time, the calculations of available horsepower to be obtained from the different streams is made.

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PREFACE.

The statistics of all the minerals included in the following pages have been collected in cooperation with the United States Geological Survey, and have been compiled by Mr. Abele from advance chapters of the *Mineral Resources of the United States,* a publication of the Federal Survey.

The introductory and general matter in each of these articles has either been taken without change from the U. S. advance chapters or has been rearranged or condensed from these chapters, or entirely rewritten to suit it for our present purposes. In each case credit is given to the author.

STATISTICS OF THE MINERAL PRODUCTION OF ALABAMA FOR 1912.

ABRASIVES.

EUGENE A. SMITH.

ALABAMA'S production of abrasives is at present limited to a small number of millstones; there are, however, several materials in different parts of the State which are sufficiently promising to be worth investigation and thorough testing; the nature and locality of these deposits were treated in Bulletin No. 13, which see.

BAUXITE.

THE production of bauxite in Alabama in 1912 was 14,173 long tons valued at $60,254. This was an increase of 5,325 long tons, or 60.18 per cent over the production of 1911, and the increase in value amounted to $24,862, or 70.25 per cent.

Below are presented in tabular form the foregoing figures:

Production of bauxite in Alabama in 1911 and 1912.

	Quantity (Tons)	Value	Percentage of Total U. S. Production.	Percentage of Total U. S. Value.
1911	8,848	$35,392	5.68	4.71
1912	14,173	60,254	8.86	7.83
Increase	5.325	24,862		
Per cent	60.18	70.25		

The following table gives the production and value of Bauxite from 1889 to 1912 inclusive:

Production of bauxite in the United States, 1889-1912, by States, in long tons.

Year	Georgia	Alabama	Arkansas	Total	Value
1889	728	-------	-----------	728	$2,366
1890	1,844	-------	-----------	1,844	6,012
1891	3,301	292	-----------	3,593	11,675
1892	5,110	5,408	-----------	10,518	34,183
1893	2,415	6,764	-----------	9,179	29,507
1894	2,050	9,016	-----------	11,066	35,818
1895	3,756	13,313	-----------	17,069	44,000
1896	7,313	11,051	-----------	18,364	47,338
1897	7,507	13,083	-----------	20,590	57,652
1898	-------	-------	-----------	25,149	75,437
1899	15,736	14,499	5,045	35,280	125,598
1900	19,739		3,445	23,184	89,676
1901	18,038		867	18,905	79,914
1902	22,677		4,645	27,322	120,366
1903	22,374		25,713	48,087	171,306
1904	21,913		25,748	47,661	235,704
1905	15,173		32,956	48,129	240,292
1906	25,065		50,267	75,332	368,311
1907	---------------		-----------	*97,776	480,330
1908	14,464		*37,703	52,167	263,968
1909	22,227		*106,874	129,101	679,447
1910	33,096		*115,836	148,932	716,258
1911	30,170		*125,448	155,618	750,649
1912	19,587	14,173	*126,105	159,865	768,932

*Production of Tennessee included.

For an outline of the uses of bauxite, see Bulletin No. 13.

CEMENT

OWING to the fact that there was in Alabama in 1912 only one producer of puzzolan cement, and not more than two operating plants in the Portland cement industry, it is necessary to combine the productions of both industries in order to avoid publishing figures which were given the Survey in confidence. The tabular results of such a combination are, however, necessarily inconsistent and not to be taken too literally, since the weights per barrel of the two kinds of cement vary.

The total quantity of Portland and puzzolan cement produced in Alabama in 1912 was 726,688 barrels, valued at $608,620, as compared with 593,911 barrels in 1911, valued at $529,359, or an increase in production of 132,777 barrels, or 22.35 per cent, giving an increase in value of $119,261, or 22.53 per cent. The percentages of increase in quantity and value are notably less than in 1911.

Below are presented in tabular form the foregoing figures:

Production and value of cement (including puzzolan and Portland) in Alabama in 1911 and 1912.

	No. of Producers	Quantity (Bbls.)	Value	Value of Total U.S. Percentage
1911	3	593,911	$529,359	0.79
1912	3	726,688	608,620	0.92
Increase		132,777	119,261	
Per cent.		22.35	22.53	

A review of the puzzolan cement industry in the United States for the past five years is given in the following table:

Statistics of the Puzzolan-Cement Industry, 1908-1912.

	1908	1909	1910	1911	1912
Number of plants reporting production:					
Alabama	1	1	1	1	1
Illinois	------	------	------	------	------
Kentucky	------	------	------	------	------
Maryland	------	------	------	------	------
New Jersey	------	------	------	------	------
New York*	------	------	------	1	1
Ohio	2	2	2	1	1
Pennsylvania	1	1	1	1	1
Total	4	4	4	4	4
Production in barrels of 380 pounds	151,451	160,646	95,951	93,230	91,864
Value of production	$95,468	$99,453	$68,286	$77,786	$77,363

*Includes production of Collos cement in 1911 and 1912.

For a full account of the cement resources of Alabama, see Bulletins No. 8 and No. 13.

CLAY AND CLAY PRODUCTS.

JEFFERSON MIDDLETON AND C. A. ABELE.

CLAY.

CLAY available for the manufacture of clay products is one of the most widely spread of our minerals. Clay miners are usually also the manufacturers of the lower-grade clays, but as the higher grades of ware are reached, the rule is that fewer and fewer manufacturers are also miners, until in the highest grades of ware the rule is that the manufacturer is not the miner of the clays that he uses. The figures given in the following tables represent clay that is mined and not manufactured by the miner, but is sold as clay. The clay thus sold is small in quantity compared with that consumed and includes mainly clay used for refractory products.

The clay-mining industry showed a marked increase in Alabama in 1912, both in production and value. While the production was less than 60 per cent of that in 1910, the value was only 12 per cent less than in that year.

The total production of clay, which was later sold as such in 1912, was 43,052 short tons, valued at $33,414. This was an increase in both quantity and value of 8,249 short tons, or 23.43 per cent, and $3,505, or 11.72 per cent respectively. In 1912 clay other than fire-clay was again sold.

Below is a table giving the production and value of clay from 1908 to 1912, inclusive, and also a comparison of the years 1911 and 1912.

Production of clay from 1908 to 1912 inclusive, and a comparison of the production in 1911 and 1912.

	Fire-Clay		Miscellan. Clay		Total	
	Quantity Short Tons	Value	Quantity Short Tons	Value	Quantity Short Tons	Value
1908	68,289	$48,983	24,000	$12,000	92,289	$60,983
1909	45,137	35,345	18,271	5,587	63,408	40,932
1910	54,482	32,395	20,600	5,650	75,082	38,045
1911	35,203	29,909	------	------	35,203	29,909
1912	38,552	31,414	4,500	2,000	43,052	33,414
Increase	3,349	1,505	------	------	8,249	35,05
Per cent.	9.15	5.08	------	------	23.43	11.72

Quantity and value of clay mined in 1912.

Kind	Quantity Mined (Short Tons)	Value	Average Value Per Ton	Percentage of Total U. S. Value
Fire clay	38,552	$31,414	$0.81+	1.33
Miscellaneous clay	4,500	2,000	0.44+	0.76
Total	43,052	33,414	----------	0.89

CLAY-WORKING INDUSTRIES.

The total value of all clay products in Alabama in 1912 was $1,935,179, a decrease of $11,923, or 0.61 per cent, from 1911. The principal product is common brick, this item in 1912 being valued at $759,409 and representing 39.24 per cent of the value of all of Alabama's clay products in that year. Vitrified, fire, and front brick combined represent a value approximating that of common brick alone, so that the output of the brickyards made up nearly 80 per cent of the State's total. Clays suitable for tile and pottery are available in the State, but these branches of the industry have not been extensively developed, the value of the pottery production being only $22,213 in 1912.

Jefferson County is the principal clay-working county, reporting a production valued at $1,135,339, or 58.67 per cent, of the value reported for the State. All of the fire brick produced in the State is reported from Jefferson County though vitrified brick is the principal product. Only one other county in the State, St. Clair produces vitrified brick. The leading counties in the manufacture of common brick are Jefferson, Montgomery and Russell.

Clay products of Alabama, 1908-1912

Product	1908	1909	1910	1911	1912
Brick:					
Common—					
Quantity	120,237,000	146,180,000	135,785,000	129,694,000	136,989,000
Value	$690,963	$799,693	$746,961	$708,903	$759,409
Average per M.	$5.75	$5.47	$5.50	$5.47	$5.54
Vitrified—					
Quantity	18,248,000	20,444,000	19,772,000	21,444,000	26,480,000
Value	$244,084	$262,376	$236,516	$246,707	$353,303
Average per M.	$13.38	$12.83	$11.96	$11.50	$13.34
Front—					
Quantity	(*)	(*)	(*)	9,169,000	10,629,000
Value	(*)	(*)	(*)	$128,403	$132,033
Average per M.	$17.89	$16.19	$15.96	$14.00	$12.42
Fancy value	(*)	(*)	---------	(*)	(*)
Fire value	$122,354	$196,887	$163,672	$193,375	$240,434
Draintile value	$2,046	(*)	$3,773	$3,777	$5,465
Sewer pipe value	(*)	(*)	(*)	(*)	(*)
Fireproofing value	(*)	(*)	(*)	(*)	(*)
Pottery:					
Red earthenware value	$15,058	$11,886	$3,475	$11,243	$10,990
Stoneware and yellow and Rockingham ware value	$9,031	$24,453	$16,371	$14,753	$11,228
Miscellaneous value	$476,070	$404,832	$496,791	$639,941	$422,322
Total value	$1,559,606	$1,700,127	$1,667,559	$1,947,102	$1,935,179
Number of operating firms reporting	103	100	87	82	74
Rank of State	19	22	22	17	17

*Included in "Miscellaneous."

BRICK AND TILE.

The total common brick production in 1912 was 136,989 M, valued at $759,409. This represented an increase in both quantity and value of 7,295 M, or 5.62 per cent, and $50,506 or 7.13 per cent, respectively. The decrease in 1911 was over-

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Russell.

products of Alabama, 1908-1912

	1908	1909	1910	1911	1912
	120,237,000	146,180,000	[illegible]	[illegible]	[illegible]
	$690,963	$799,493	[illegible]	[illegible]	[illegible]
	$5.75	$5.47	[illegible]	[illegible]	[illegible]
	18,248,000	20,444,000	[illegible]	[illegible]	[illegible]
	$244,084	$262,376	[illegible]	[illegible]	[illegible]
	$13.38	$12.83	[illegible]	[illegible]	[illegible]
	(a)	(a)	(a)		
	(a)	(a)	(a)	[illegible]	[illegible]
	$17.89	$16.1[illegible]	[illegible]	[illegible]	[illegible]
value	(a)	(a)		[illegible]	[illegible]
value	[illegible]	[illegible]	[illegible]	(a)	[illegible]
value	[illegible]	(a)	[illegible]	[illegible]	(a)
value	(a)	(a)	(a)	[illegible]	[illegible]
value	(a)	(a)	(a)	(a)	[illegible]
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				[illegible]	[illegible]

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come in 1912, the 1912 production being 1,204 M more than in 1910, the resulting increase in value being $12,448. All other types of brick and tile production, excepting that of miscellaneous brick, showed a marked increase over that of 1911; miscellaneous brick, which includes those types which are manufactured by less than three producers, showed a notable decrease in value in 1912, the decrease in this one class being sufficient to counteract the increase in value of all other classes and to lower the value of the 1912 production $5,640 or 0.29 per cent.

The following tables give a review of the brick and tile industry in Alabama in 1911 and 1912.

Production of brick and tile in 1912

Kind	Quantity M.	Value	Av'g. Value per M.	Percentage of Total Value of Brick & Tile	Percentage of Total U. S. Value
Common Brick	136,989	$759,409	$5.54	39.69	1.46
Vitrified brick	26,480	353,303	13.34	18.46+	2.23
Front Brick	10,629	132,033	12.42	6.95	1.39
Fire Brick	9,930	240,434	24.21	12.55+	1.60
Drain Tile	----------	5,465	--------	0.28+	0.06
Miscellaneous	----------	*422,322	--------	22.06+	1.67
Total	----------	$1912,966	--------	100.00	1.40

*This value includes fancy brick, sewer pipe, fireproofing, and silica brick.

Production of brick and tile in 1911 and 1912.

Kind	1911			1912			Increase or Decrease in Value	Percentage
	Quantity	Value	Av'g. Price	Quantity	Value	Av'g. Price		
Common Brick	129,694	$708,903	$5.47	136,989	$759,409	$5.54	+$50,506	+ 7.13
Vitrified Brick	21,444	246,707	11.50	26,480	353,303	13.34	+106,596	+43.22
Front Brick	9,169	128,403	14.00	10,629	132,033	12.42	+ 3,630	+ 2.82
Fire Brick	11,929	193,375	16.21	9,930	240,434	24.21	+ 47,059	+24.33
Drain Tile	------	3,777	----	------	5,465	----	+ 1,688	+44.69
Miscellaneous	------	637,441	----	------	*422,322	----	—215,119	—33.74
Total	------	1,918,606	----	------	1,912,966	----	— 5,640	— 0.29

*Includes Fancy Brick, Sewerpipe, Fireproofing and Silica Brick.

POTTERIES.

The pottery industry of Alabama is of relatively small importance, as only the commoner and coarser grades of ware are produced, and most of this for local trade only. Production was reported by 15 operators whose total output was valued in 1912 at $22,213, which was a decrease of $6,283 from 1911. The products consisted entirely of red earthenware and stoneware in nearly equal proportions.

The following tables give the values of pottery produced in 1911 and 1912, and also a comparison of the production and values in these years.

Value of pottery products in 1912.

Kind	Value	Percentage of Total Alabama Potteries	Percentage of Total U. S. Value
Red Earthenware	$10,990	49.47+	1.14
Stoneware and Rockingham ware	11,223	50.52+	0.23+
Total	22,213	100.00	0.62

Comparison of pottery products in 1911 and 1912.

Kind	1911	1912	Decrease	Percentage
Red Earthenware	$11,243	$10,990	+ $253	2.25
Stoneware and Rockingham ware	17,253	11,223	6,030	34.95
Total	28,496	22,213	6,283	22.05

COAL.

E. W. PARKER.

TOTAL production in 1912, 16,100,600 short tons; spot value, $20,829,252. The returns to the Survey for the calendar year 1912 show that the preliminary estimates of the production published early in the year were considerably in excess of the actual output. The preliminary estimates indicated that the production would exceed the record of 16,111,462 short tons made in 1910. The final results show that it fell about 10,000 tons short of that figure, and amounted to 16,100,600 short tons. This was an increase of 1,079,179 tons, or 7.18 per cent, over 1911, when it amounted to 15,021,421 tons. The value increased somewhat more in proportion—$1,749,303, or 9.17 per cent—from $19,079,949 in 1911 to $20,829,252. The value of the 1912 production exceeded that of the slightly larger tonnage of 1910 by nearly $600,000. The principal local increases in 1912 were in Walker County, 444,367 tons; Jefferson County, 398,459 tons; St. Clair County, 220,542 tons, and Bibb County, 148,138 tons. Two counties showed decreases, Tuscaloosa, 150,691 tons, and Etowah, 84,552 tons.

Rank of first ten coal-producing States in 1911 and 1912, with quantity and value of products and percentage of each.

1911.

Production				Value			
Rank	State or Territory	Quantity (short tons)	Percentage of total proruct'n	Rank	State or Territory	Value	Percentage of total value
1	Pennsylvania:			1	Pennsylvania:		
	Anthracite	90,464,067	18.2		Anthracite	$175,189,392	28.0
	Bituminous	144,561,257	29.1		Bituminous	146,154,952	23.3
2	West Virginia	59,831,580	12.1	2	Illinois	59,519,478	9.5
3	Illinois	53,679,118	10.8	3	West Virginia	53,670,515	8.6
4	Ohio	30,759,986	6.2	4	Ohio	31,810,123	5.1
5	Alabama	15,021,421	3.0	5	Alabama	19,079,949	3.0
6	Indiana	14,201,355	2.9	6	Indiana	15,326,808	2.4
7	Kentucky	14,049,703	2.8	7	Colorado	14,747,764	2.4
8	Colorado	10,157,383	2.1	8	Kentucky	14,008,458	2.3
9	Iowa	7,331,648	1.5	9	Iowa	12,663,507	2.0
10	Virginia	6,864,667	1.4	10	Wyoming	10,508,863	1.7

1912.

Production				Value			
Rank	State or Territory	Quantity (short tons)	Percentage of total proruct'n	Rank	State or Territory	Value	Percentage of total value
1	Pennsylvania:			1	Pennsylvania:		
	Anthracite	84,361,598	15.8		Anthracite	$177,622,626	25.6
	Bituminous	161,865,488	30.3		Bituminous	169,370,497	24.4
2	West Virginia	66,786,687	12.5	2	Illinois	70,294,338	10.1
3	Illinois	59,885,226	11.2	3	West Virginia	62,792,234	9.0
4	Ohio	34,528,727	6.4	4	Ohio	37,083,363	5.3
5	Kentucky	16,490,521	3.1	5	Alabama	20,829,252	3.0
6	Alabama	16,100,600	3.0	6	Indiana	17,480,546	2.5
7	Indiana	15,285,718	2.8	7	Kentucky	16,854,207	2.4
8	Colorado	10,977,824	2.0	8	Colorado	16,345,336	2.4
9	Virginia	7,846,638	1.5	9	Iowa	13,152,088	1.9
10	Wyoming	7,368,124	1.4	10	Wyoming	11,648,088	1.7

The statistics of the production of coal in Alabama in 1911 and 1912, with the distribution of the product for consumption, are shown in the following table:

Coal production of Alabama in 1911 and 1912, by counties, in short tons.

1911.

County	Loaded at mines for shipment	Sold to local trade and used by employees	Used at mines for steam and heat	Made into coke	Total quantity	Total value	Average price per ton	Average number of days active	Average number of employees
Bibb ____________	1,515,976	9,592	107,629	_______	1,633,197	$2,407,918	$1.47	239	2,631
Blount __________	80,266	1,900	100	_______	82,266	98,599	1.20	225	189
Etowah __________	252,866	720	2,274	_______	255,860	360,307	1.40	189	492
Jefferson _______	4,804,221	86,017	307,265	2,578,887	7,776,390	9,668,726	1.24	246	10,665
St. Clair _______	509,120	1,584	18,507	_______	529,211	673,576	1.27	240	682
Shelby __________	430,505	2,723	29,861	_______	463,089	757,772	1.64	240	866
Tuscaloosa _____	585,666	9,310	61,624	375,058	1,031,658	1,288,235	1.25	265	1,445
Walker __________	2,820,521	25,077	82,610	175,387	3,103,595	3,598,720	1.16	180	5,360
Winston ________	16,074	350	______	_______	16,424	25,185	1.50	67	129
Other counties* & small mines	120,348	3,918	5,465	_______	129,731	200,911	1.55	170	248
Total_____	11,135,563	141,191	615,335	3,129,332	15,021,421	19,079,949	1.27	227	22,707

1912.

County	Loaded at mines for shipment	Sold to local trade and used by employees	Used at mines for steam and heat	Made into coke	Total quantity	Total value	Average price per ton	Average number of days active	Average number of employees
Bibb ____________	1,622,198	9,823	109,314	_______	1,781,335	$2,621,682	$1.47	272	2,948
Blount __________	143,603	1,139	1,600	_______	146,342	181,036	1.24	211	282
Etowah __________	166,366	3,067	1,875	_______	171,308	249,749	1.46	265	260
Jefferson _______	6,168,715	81,368	339,211	1,585,555	8,174,849	10,433,728	1.28	251	10,922
St. Clair _______	722,276	2,456	25,021	_______	749,753	959,219	1.28	291	725
Shelby __________	463,788	3,501	29,660	_______	496,949	872,501	1.76	250	878
Tuscaloosa _____	631,114	12,038	48,863	188,952	880,967	1,091,882	1.24	239	1,220
Walker __________	3,271,284	32,030	102,681	141,967	3,547,962	4,158,094	1.17	211	5,079
Winston ________	18,550	105	75	_______	18,730	27,793	1.48	220	57
Other counties† & small mines_	124,627	2,059	5,719	_______	132,405	233,568	1.76	229	242
Total_____	18,372,521	147,586	664,019	1,916,474	16,100,600	20,829,252	1.29	245	22,613

Cullman, DeKalb, Jackson, and Marion. †Cullman, Jackson, and Marion.

In the following table is presented a statement of the production of coal in Alabama, by counties, during the last five years, with increase and decrease in 1912 as compared with 1911:

Coal production of Alabama, 1908-1912, by counties, in short tons.

County	1908	1909	1910	1911	1912	Increase (+) or decrease (—), 1912.
Bibb	1,166,548	1,338,243	1,580,564	1,633,197	1,781,335	+ 148,138
Blount	*181,062	*186,261	*235,456	*210,070	*276,429	+ 66,359
Cullman						
Etowah	8,880	46,194	172,465	255,860	171,308	— 84,552
Jefferson	5,914,129	7,176,922	8,298,702	7,776,390	8,174,849	+ 398,459
St. Clair	193,434	354,005	428,409	529,211	749,753	+ 220,542
Shelby	407,547	524,925	488,141	463,089	496,949	+ 33,860
Tuscaloosa	712,101	1,006,989	1,081,219	1,031,658	880,967	— 150,691
Walker	2,941,836	2,973,776	3,788,479	3,103,595	3,547,962	+ 444,367
Winston	28,408	32,278	16,442	16,424	18,730	+ 2,306
Other counties and small mines	50,648	63,857	21,585	1,927	2,318	+ 391
Total	11,604,593	13,703,450	16,111,462	15,021,421	16,100,600	+ 1,079,179
Total value	$14,647,891	$16,306,236	$20,236,853	$19,079,949	$20,829,252	+ $1,749,308

The great Appalachian coal region which furnishes over two-thirds of the coal production of the United States and which extends from Ohio and Pennsylvania on the north in a gradually narrowing belt through eastern Kentucky and Tennessee has its southern terminus in a considerably broadened area that occupies a large part of the northern half of Alabama. The coal-bearing formations of Alabama underlie about 8,400 square miles and are divided into four distinct basins, the Coosa, the Cahaba, and the Warrior, named from the rivers which drain them, and the Plateau, which includes Blount, Lookout, and Sand or Raccoon Mountains. By far the most important basin in area and in production is the Warrior, which includes all of Walker County, most of Jefferson, Tuscaloosa, and Fayette counties, and smaller parts of Blount, Cullman, Winston, and Marion counties. The area known to contain coal is approximately 4,000 square miles, or one-half the total coal area of the State, and contributes about 80 per cent of the total production.

There are several distinct coal groups in the basin, the most important of which are the Brookwood, the Pratt, and the Mary Lee, designated by the names of their principal beds. The Mary Lee group includes the Blue Creek, the Jagger, and the

Newcastle beds, most of which are mined in places. The Brookwood, the Pratt, and the Mary Lee produce most of the coking coal mined in the State, and more than half of all of the coal mined in the district.

The Cahaba Basin, second in importance, is a long narrow syncline, 68 miles long and about 6 miles wide, southeast of the Warrior, and occupies parts of St. Clair, Jefferson, Shelby, and Bibb counties. There are many workable beds and the total quantity of coal in the basin is large. The production is something over 10 per cent of the total for the State.

The Coosa Basin is a deep syncline east of the Cahaba and parallel with it, extending across Shelby and St. Clair counties. It is also long and narrow, 60 miles long by 6 miles wide. It has not been thoroughly explored, but in different parts of the area from two to twelve beds, 3 or more feet in thickness, have been reported.

The Plateau field embraces parts of Blount, Etowah, Dekalb, Cherokee, Marshall, and Jackson counties, and although it has an area underlain by coal four times that of the Cahaba and the Coosa combined, the resources in Alabama are comparatively small. There are four to six beds locally workable.

For maps of the Alabama coal fields, apply to the State Geologist, University of Alabama.

So far as known, the earliest record of the existence of coal in Alabama was made in 1834. The first statement of production in the State is contained in the United States census report for 1840, in which year the production is given as 946 tons. The census report for 1850 does not mention any coal production for the State, and the next authentic record is contained in the census statistics of 1860, when Alabama is credited with an output of 10,200 short tons. The mines of Alabama were probably worked to a considerable extent during the Civil War, but there are no records of the actual production until 1870, for which year the United States census reports a production of 11,000 tons. Ten years later the production had increased to 323,972 short tons, but the development of the present great industry really began in 1881 and 1882, when attention was directed to the large iron deposits near the city of Birmingham, and thus the great "boom" of that city and vicinity was inaugurated. By 1885 the coal production of the State had increased to nearly 2,500,000 tons. Then followed a period of relapse and liquidation, which lasted two years, after which business settled down to a conservative and rational basis and has since developed steadily. In 1902 the coal production of the State reached a total of more than 10,000,000 tons, and reached the maximum of 16,111,462 tons in 1910.

The statistics of production in Alabama from 1840 to the close of 1912 are shown in the following table:

Production of coal in Alabama from 1840 to 1912, in short tons.

Year	Quantity	Year	Quantity	Year	Quantity	Year	Quantity
1840----	946	1859----	9,000	1878----	224,000	1897----	5,893,770
1841----	1,000	1860----	10,200	1879----	280,000	1898----	6,535,283
1842----	1,000	1861----	10,000	1880----	323,972	1899----	7,593,416
1843----	1,200	1862----	12,500	1881----	420,000	1900----	8,394,275
1844----	1,200	1863----	15,000	1882----	896,000	1901----	9,099,052
1845----	1,500	1864----	15,000	1883----	1,568,000	1902----	10,354,570
1846----	1,500	1865----	12,000	1884----	2,240,000	1903----	11,654,324
1847----	2,000	1866----	12,000	1885----	2,492,000	1904----	11,262,046
1848----	2,000	1867----	10,000	1886----	1,800,000	1905----	11,866,069
1849----	2,500	1868----	10,000	1887----	1,950,000	1906----	13,107,963
1850----	2,500	1869----	10,000	1888----	2,900,000	1907----	14,250,454
1851----	3,000	1870----	11,000	1889----	3,572,983	1908----	11,604,593
1852----	3,000	1871----	15,000	1890----	4,090,409	1909----	13,703,450
1853----	4,000	1872----	16,800	1891----	4,759,781	1910----	16,111,462
1854----	4,500	1873----	44,800	1892----	5,529,312	1911----	15,021,421
1855----	6,000	1874----	50,400	1893----	5,136,935	1912----	16,100,600
1856----	6,800	1875----	67,200	1894----	4,397,178		
1857----	8,000	1876----	112,000	1895----	5,693,775	Total--	237,275,836
1858----	8,500	1877----	196,000	1896----	5,748,697		

The evolution in making coke in the United States and the gradual shifting of this related industry from the coal-mining region to the centers of population and manufacture is interestingly shown in the statistics of coal production of Alabama. According to the returns the quantity of coal made into coke decreased from 4,417,443 tons in 1910 to 3,129,332 tons in 1911, and to 1,916,474 tons in 1912, whereas the actual quantities of coal made into coke in the State were 5,272,322 tons in 1910, 4,411,298 tons in 1911, and 4,585,498 tons in 1912. The reason for this apparent discrepancy lies in the fact that in the two later years the proportion of coal made into coke in by-product ovens has materially increased and as these ovens are located at the blast furnaces, or in or near the larger cities, the coal shipped to them appears as a part of the product "loaded at mines for shipment" and not as coal made into coke at the mines. The quantity of Alabama coal made into coke in 1912 at points distant from the mines was nearly one and a half times that used at ovens near the mines.

Coal mining in Alabama in 1912 gave employment to 22,613 men for an average of 245 days, against 22,707 men for 227 days in 1911, the larger production in 1912 being accomplished through the additional working time. The average production per man in 1912 was 712 tons against 662 in 1911, but the average daily production per man was lower in 1912, 2.91 tons against 2.92 tons in 1911. Most of the mines in Alabama are operated 10 hours a day.

Average production per man compared with hours worked per day, and average number of days worked 1910-1912.

Year	8 hours		9 hours		10 hour		All others	Total	Days Worked	Average Tonnage	
	Mines	Men	Mines	Men	Mines	Men	Men	Men		Per Year	Per Day
1910	18	766	36	2,633	134	17,306	1,525	22,230	249	725	2.91
1911	15	550	50	5,345	102	12,628	4,184	22,707	227	662	2.92
1912	11	338	46	4,145	107	13,938	4,192	22,613	245	712	2.91

The production by machines increased from 2,936,512 tons in 1911 to 3,742,549 tons in 1912, and the percentage of machine-mined coal to the total increased from 19.6 to 23.2. There were 353 machines in use in 1912, an increase of 81 over 1911 and of 36 over 1910. Several mines equipped with machines were either idle or did not use their full equipment in 1911. Of the 353 machines in 1912, 222 were punchers, 60 were chain breast, 12 were long wall, and 59 short wall.

Number and kind of machines in use, and average production per man compared with production by machines, by short tons, in 1911 and 1912.

Year	Pick	Chain Breast	Long-Wall	Short-Wall	Total	Average Tonnage		Production by Machines	
						Per year	Per day	Total Tonnage by Machines	% of Machined Coal to State Total
1911	184	53	13	22	272	662	2.92	2,936,512	19.55
1912	222	60	12	59	353	712	2.91	3,742,549	23.2
Increase or decrease	+ 38	+ 7	— 1	+ 37	+ 81	+ 50	— .01	+ 806,037	----
Per cent	20.65	13.20	9.23	168.18	29.77	7.57	-----	20.64	----

Of the Alabama production not mined by machines 5,658,457 tons, or 35.1 per cent of the total, were shot off the solid, and 6,658,732 tons, or 41.4 per cent, were mined by hand.

Quantity and percentage of bituminous coal produced by different methods in 1911 and 1912.

Year	Mined by Hand	Percentage	Shot off the Solid	Percentage	Mined by Machines	Percentage	Not reported	Percentage	Total Production
1911	4,673,719	36.1	6,623,252	44.1	2,936,512	19.6	787,938	5.2	15,021,421
1912	6,658,732	41.4	5,658,457	35.1	3,742,549	23.2	40,862	0.3	16,100,600
Increase or decrease	+1,985,013	---	— 964,795	---	+ 806,037	---	—747,112	--	+1,079,179
Percentage	+ 42.49	---	— 14.56	---	+ 27.44	---	— 94.81	--	+ 7.18

There were 7,187,211 tons of coal washed in 1912, yielding 6,325,946 tons of cleaned coal and 861,265 tons of refuse. A large part of the washed coal is used for making coke.

Quantity and percentage of coal washed, by short tons, in 1911 and 1912.

	Quality of Coal Washed	Percentage of Coal Mined	Quantity of Clean Coal	Refuse	
				Quantity	% of Total Coal Washed
1911	6,251,828	41.61	5,538,401	713,427	11.41
1912	7,187,211	44.64	6,325,946	861,256	11.98
Increase	935,383	------	787,545	147,829	------
Percentage	14.96	------	14.22	20.72	------

According to the United States Bureau of Mines there were 121 fatal accidents in the coal mines of Alabama in 1912, a decided improvement over 1911, when, because, of several explosions and frequent deaths from windy shots, the aggregate number of fatalities was 209. Of the 121 deaths in 1912, 110 occurred underground, 61 of them due to falls of roof and coal, 25 to explosions of gas and dust, 11 to mine cars and locomotives, 9 to electrical shocks and burns, and 3 to explosives, including premature blasts, etc. Four deaths occurred in shafts and 7 on the surface.

There were no strikes of serious consequence during the year, the record showing 384 men idle for an average of 32 days.

Statistics of labor troubles 1910-1912.

Year	Number of Men on Strike	Percentage of Total Men Working	Total Days Lost	Average Number of Days Lost Per Man
1910	25	0.11	1,250	50
1911	210	0.92	1,260	6
1912	384	1.69	12,323	32

COKE.

E. W. PARKER.

ALABAMA'S output of coke in 1912 amounted to 2,975,489 short tons valued at $8,098,412, against 2,761,521 short tons, valued at $7,593,594, in 1911, the increase in 1912 being 213,968 tons, or 7.75 per cent, in quantity and $504,818, or 6.65 per cent, in value. Alabama retained in 1912 second place in the rank of coke-producing States, it having superseded West Virginia in 1911.

Rank of the first five states in the production of coke, 1907-1912.

State	1907	1908	1909	1910	1911	1912
Pennsylvania	1	1	1	1	1	1
Alabama	3	3	3	3	2	2
Indiana	—	—	—	—	—	3
West Virginia	2	2	2	2	3	4
Illinois	10	9	5	4	4	5

Comparison of the production and value of coke in Alabama in 1911 and 1912.

	No. of Ovens	Coal Charged (Short Tons)	Coke Produced (Short Tons)	Total Value of Coke Ovens	Percent of Total U. S. Value
1911	10,121	4,411,298	2,761,521	$7,593,594	9.02
1912	10,208	4,585,498	2,975,489	8,098,412	7.24
Increase	87	174,200	213,968	504,818	----------
Percentage	0.86	3.95	7.75	6.65	----------

The average price per ton for Alabama coke has declined from $2.82 in 1910 to $2.75 in 1911, and to $2.72 in 1912. This does not necessarily indicate an actual decline in the price of coke. A large proportion, possibly over 90 per cent, of Alabama coke is consumed in furnaces which are owned by the same interests owning and operating the coal mines and coke ovens, and the placing of a value on the coke is largely a matter of accounting.. The lower value per ton of the coke produced in 1912 was in spite of the fact that the value of the coal used advanced from $1.28 in 1911 to $1.35 in 1912.

That Alabama has developed her coking industry along the lines of modern practice is evinced by the fact that in each of the last three years the only new ovens under construction on December 31 were retort ovens. During 1912 there were 195 beehive ovens abandoned and 2 were rebuilt, a net loss in this type of ovens of 193. The number of retort ovens on the other hand, increased from 340 in 1911 to 620 in 1912, and there were 100 additional retort ovens under construction at the end of the year. The present installations of retort ovens in Alabama are 280 Semet-Solvay ovens and 340 Koppers ovens. The former include 240 Semet-Solvay ovens at Ensley (one-half completed in 1898 and the other half in 1902) and 40 at Tuscaloosa, which were completed in 1906. The 340 Koppers ovens include 60 completed during 1911 by the Woodward Iron Co., at Woodward, and 280 completed in 1912 by the Tennessee Coal, Iron & Railroad Co., at Corey. The 100 new ovens under construction at the end of the year consisted of 80 Koppers ovens building at Woodward and 20 Semet-Solvay ovens building at Tuscaloosa. There were 46 establishments in Alabama in 1912, an increase of 2 over 1911, but although 280 retort ovens were added during 1912 the total number of ovens increased only 87, or from 10,121 to 10,208, indicating that there was a decrease of 193 in the number of beehive ovens. Of the 46 establishments in Alabama, 18, with a total of 2,902 ovens, were idle. In addition to these there were 597 ovens, portions of other establishments, that were idle during the year. The number of active ovens was 6,709 and the average production per oven was 444 tons, against 337 tons per oven in 1911 and 338 tons in 1910, these figures again showing the influence of the operations of retort ovens on Alabama's production.

The production of coke in Alabama in 1880, 1890, 1900, and from 1908 to 1912 is shown in the following table:

Statistics of the manufacture of coke in Alabama, 1880-1912.

Year	Establishments	Ovens		Coal Used (Short Tons)	Yield of Coal in Coke (per cent)	Coke Produced (Short Tons)	Total Value of Coke at Ovens	Value of Coke at Ovens Per Ton
		Built	Building					
1880	4	316	100	106,283	57.0	60,781	$183,063	$3.01
1890	20	4,805	371	1,809,964	59.0	1,072,942	2,589,447	2.41
1900	30	6,529	690	3,582,547	58.9	2,110,837	5,629,423	2.67
1908	45	10,103	0	3,875,791	61.0	2,362,666	7,169,901	3.04
1909	43	10,061	0	5,080,764	60.7	3,085,824	8,068,267	2.61
1910	43	10,132	340	5,272,322	61.6	3,249,027	9,165,821	2.82
1911	44	10,121	280	4,411,298	62.6	2,761,521	7,593,594	2.75
1912	46	*10,208	†100	4,585,498	64.9	2,975,489	8,098,412	2.72

*Includes 280 Semet-Solvay and 340 Koppers ovens.
†80 Koppers and 20 Semet-Solvay ovens.

Most of the coal used in the manufacture of coke in Alabama is washed before being charged into the oven. In 1912, out of a total of 4,585,498 tons, 3,819,400 tons, or 83 per cent, were washed. Of the washed coal used 2,922,979 tons were slack and 896,421 tons were run of mine. The unwashed coal was principally mine run, there being 747,305 tons of unwashed run-of-mine coal used and 18,793 tons of unwashed slack.

The character of the coal used in the manufacture of coke in Alabama in 1890, 1900, and for the last five years, is shown in the following table:

Character of coal used in the manufacture of coke in Alabama, 1890-1912, in short tons.

Year	Run of Mine		Slack		Total
	Unwashed	Washed	Unwashed	Washed	
1890	1,480,669	0	206,106	123,189	1,809,964
1900	1,729,882	152,077	165,418	1,535,170	3,582,547
1908	548,093	1,457,360	53,218	1,817,120	3,875,791
1909	713,992	2,153,081	0	2,212,971	5,080,764
1910	771,931	1,308,085	0	3,192,806	5,272,322
1911	693,135	1,295,109	2,937	2,420,117	4,411,298
1912	747,305	896,421	18,793	2,922,979	4,585,498

GOLD AND SILVER.

H. D. M'CASKEY.

THE mine production of gold in Alabama in 1912 was 809.02 fine ounces, valued at $16,724, and of silver, 168 fine ounces, valued at $103, against 915.06 fine ounces of gold, valued at $18,916, and 171 fine ounces of Silver, valued at $91, in 1911, The gold output was all from gold-quartz mines in 1912 and the silver production was entirely from refining the gold bullion produced. No copper, lead, or zinc output was reported from Alabama in either 1912 or 1911.

The following table shows the mine production of gold and silver in Alabama since 1905, when the United States Geological Survey first collected detailed figures from the mines of the Eastern States:

Production of gold and silver in Alabama from 1905 to 1912 inclusive.

	Ore Sold or Treated (Short Tons)	Gold		Silver		Total Value
		Quantity oz.	Value	Quantity oz.	Value	
1905	16,425	2,009.0	$41,530	336	208	$41,738
1906	8,565	1,137.0	24,921	124	83	25,004
1907	18,400	1,256.9	25,982	489	290	26,272
1908	11,174	1,998.4	41,208	282	149	41,357
1909	9,886	1,414.4	29,239	212	110	29,349
1910	9,763	1,662.2	33,533	268	145	33,678
1911	6,360	915.0	18,916	171	91	19,007
1912	5,693	809.0	16,724	168	103	16,827
Increase or decrease in 1912	— 667	— 106.0	—2,192	— 3	+ 12	—2.180
Percentage	—10.48	— 11.58	—11.60	—1.75	+13.18	—11.47

The production for 1912 was from 5,693 short tons of siliceous ore with an average recoverable precious metal value of $2.96 per ton, against 6,360 tons and a recovery of $2.99 in 1911 and 9,763 tons and a recovery of $3.41 in 1910.

In Clay County, near Pyriton, are several pyrite mines, all idle in 1912, whose ores were formerly sold for their sulphur content and produced residues containing gold, silver, and copper. No operations were reported from the Gold Ridge properties in Cleburne and Randolph counties, although the last-named prospects were leased and may be operated in 1913. The equipment includes a 20-stamp mill and an 80-ton cyanide plant. At the Storey prospect in Talladega County a small tonnage was again treated during operations of about two months of the 5-stamp amalgamation mill. The Tallapoosa mine, of Tallapoosa County, was also operated a short time in 1912, and produced gold on a small scale. The output was again chiefly from the Hog Mountain, or Hillabee, mines in Tallapoosa County, operated in 1912 under lease. The ores treated in 1912 were oxidized, and were all cyanided in the 75-ton plant of the company.

GRAPHITE.

E. S. BASTIN.

THE plant of the Quenelda Graphite Co. (formerly the Allen Graphite Co.), at Quenelda, was destroyed by fire but is now being rebuilt with a capacity for handling 400 tons of crude material in 10 hours. No production was reported for 1912.

The Ashland Graphite Co.'s plant, about 4½ miles west of Ashland, was idle during 1912. Some of the persons interested in this company are engaged, under the name of the Alabama Graphite Co., in developing a graphite deposit of similar character in the near vicinity. A mill was erected and began operations in August, 1912.

Production and value of graphite in 1911 and 1912.

	Quantity Lbs.	Value	Percentage of Total U. S. Quantity	Percentage of Total U. S. Value
1911	820,000	$39,000	1.40	13.51
1912	534,100	21,364	----------	----------
Decrease	285,900	17,636	----------	----------
Percentage	34.86	45.20	----------	----------

In addition to the production above given, the Alabama Graphite Company produced in 1912, 144,062 pounds, at the plant of the Ashland Graphite Company purchased by them. The total production for 1912 is, therefore, 678,162 pounds.

For a full account of the graphite deposits and workings of Clay, Chilton, and Coosa counties, see Bulletin No. 13.

IRON ORE.

EUGENE A. SMITH.

IRON ores of Alabama in the order of their economic importance are (1) red ore or hematite; (2) the brown ore or limonite; (3) the gray ore. The black band and clay iron stone have been noticed as occurring in a number of places, but only the red ore and the brown ore have been mined on any large scale.

Practically all the ore mined in Alabama is smelted in the State, the shipments out of the State being about equal to those received from other states.

The tables given below will show the rank of Alabama among the States of the Union both in the production of iron ore and in pig iron, and will show also the quantity of iron produced by charcoal and by coke respectively as fuel.

RED ORE OR HEMATITE.

Practically all the ore of this quality mined in Alabama occurs in the Clinton or Red Mountain formation. The Red Mountain ridges occur on each side of the anticlinal valleys which separate the coal fields. In places the red ore ridges are lacking on one side, usually the western, of the valleys being cut out by faults, while on the other hand the ridge may be duplicated on one side of the valley by the same faults.

In most of the valley occurrences the moderate dips of the ore bed are on the eastern side and there are also practically all of the ore mines. Murphrees Valley makes an exception to this, the moderate dips and the iron mines being on the western side. The iron ore occurs mainly in the central part of the formation in seams or beds one to five in number, which vary in thickness from a few inches to thirty feet.

While the ore seams are very persistent along the outcrop which in Alabama must be as much as 50 miles, yet they vary greatly from place to place, being either too thin or too lean for profitable working in the greater part of this distance.

The most important development of the Clinton ore in this State and in the world is along the 15 or 16 miles stretch of the east Red Mountain between Birmingham and Bessemer, and there is a practically continuous series of mines and strippings for this entire distance. Much mining of this ore has also been done near Gate City, Village Springs, Attalla, Gadsden, Round Mountain, Gaylesville, Ft. Payne, Valley Head, etc.

The completion in October, 1912, of a diamond drill boring in Shades Valley, within a mile of the base of Shades Mountain, gives a definite answer to the speculations concerning the occurrence of red ore under Shades Valley. This boring shows that there is no falling off in the thickness and quality of the ore with distance from the outcrop, and that the depth of the ore below the surface at a distance of more than 2½ miles from the outcrop on Red Mountain is not too great for shaft mining.

The elevation of the surface at the drilling is 595 feet. The top of the ore was reached at a depth of 1,902 feet and a section of the seam in descending order is:

Ore (Self-fluxing)	9 ft. 6 in.
Shale	4 in.
Ore (Siliceous)	9 ft. 6 in.

An analysis of an average sample of the drill of the core of the upper bench, made by David Hancock, shows as follows:

	Per Cent.
Metallic iron	39.51
Silica	9.94
Alumina	3.34
Calcium Carbonate	24.20
Magnesium carbonate	.78
Metallic manganese	.20
Phosphorus	.32

The importance of this demonstration of a vast increase in the amount of red ore available immediately or in the near future, cannot well be overestimated.

Production and value of hematite in Alabama in 1911 and 1912.

	Quantity (Tons)	% of Total U. S. Prod.	Value	% of Total U. S. Value
1911	3,119,696	8.43	$3,646,925	4.65
1912	3,814,361	7.42	4,638,734	4.8
Increase	694,665	---	991,809	---
Percentage	22.26	---	27.19	---

The average price per long ton of hematite in Alabama in 1911 was $1.17; in 1912, $1.16.

BROWN ORE OR LIMONITE.

This ore, the second in importance in the State and in the United States, furnished only 2.92 per cent of the total iron ore production of the United States in 1912. Of this Alabama produced 46.40 per cent, 749.242 long tons, and the State holds the *first* rank in this industry.

In the early days of iron making and up to the year 1876 this was the only ore used in the catalan forges, bloomaries, and charcoal furnaces of the State. It was then demonstrated that good iron could be made at low cost from the red ores, with coke for the fuel.

In general the limonites are considered the best of the ores of Alabama and they command the highest prices and command a ready sale.

The usual mode of occurrence is in irregular masses of concretionary origin in the residual clays resulting from the decomposition of limestones, and as a consequence the mining is uncertain and expensive. Limonite also occurs in regularly stratified seams or beds, and then it is the result of the alteration of pyrites or of carbonate ores. Practically all of the brown ore actually mined is that occurring in the residual clays above mentioned. Most of the ore before going to the furnace is washed and screened, and this manipulation, together with the cost of mining, makes it the most expensive of the iron ores, and it is therefore seldom used alone, but is usually mixed with the red ore in proportions determined by the quality of the iron desired. It is used alone in the charcoal furnaces and also in the coke furnaces when a particularly tough pig iron is wanted.

The limonite deposits are very numerous and are distributed over a broad expanse of country and in many places are known to be very extensive. In some of the deposits the ore is in nearly solid mass, in others it is much scattered, and in consequence the amount of foreign material necessary to be moved for every ton of ore produced, varies very much, not only in the different ore banks but also in the different parts of the same bank.

The deposits occur in nearly all the geological formations of the state, but in most of these the ore is either insufficient in quantity or not pure enough to be of much commercial value. The most important of the deposits, in point of extent and value, occur overlying the following formations, viz., the Knox Dolomite and the Weisner Quartzite, the Lauderdale Chert of the Lower Carboniferous, and the Lafayette. Some extensive beds of ore of inferior quality generally occur also in the Tuscaloosa formation of the Cretaceous, and in the upper part of the Lower Carboniferous and in the Metamorphic rocks.

The average price per long ton of limonite ore in Alabama in 1911 was $1.47; in 1912, $1.43.

Production and value of brown ore in Alabama in 1911 and 1912.

	Quantity (Tons)	% of Total U. S. Prod.	Value	% of Total U. S. Value
1911 ----------------------	835,886	43.96	$1,229,181	39.18
1912 ----------------------	749,242	46.40	1,095,637	37.91
Decrease ------------------	86,644	----	133,544	----
Percentage ----------------	10.36	----	10.86	----

Production of iron ore in Alabama in 1911 and 1912.

	Hematite (Long Tons)	Brown Ore (Long Tons)	Total Quantity	Value	% of Total U. S. Value
1911 ------------------	3,119,696	835,886	3,955,582	$4,876,106	5.64
1912 ------------------	3,814,361	749,242	4,776,545	5,734,371	5.86
Increase or decrease----	+ 694,665	— 86,644	+ 820,963	+ 858,265	----
Percentage -----------	+ 22.26	— 10.36	+ 20.75	+ 17.60	----

In the following table the first five States in the production of iron ore are arranged according to their rank as producers in 1911 and 1912, with regard to both the quantity and the value of the ore produced:

Rank of iron-ore producing States in 1911 and 1912, with quantity and value of product and percentage of each.

1911.

	State	Mined		Marketed			
		Quantity		Quantity		Value	
		Quantity (Long Tons)	Percentage of Total Produc'n	Quantity (Long Tons)	Percentage of Total Produc'n	Amount	Percentage of Total Value
1	Minnesota	24,645,105	56.17	23,398,406	56.94	$48,447,760	55.87
2	Michigan	10,329,089	23.54	8,945,103	21.77	23,810,710	27.46
3	Alabama	3,827,791	8.72	3,955,582	9.63	4,876,106	5.62
4	New York	1,061,279	2.42	1,057,984	2.58	2,959,009	3.41
5	Wisconsin	698,660	1.59	610,871	1.49	1,146,188	1.32

1912.

	State	Quantity (Long Tons)	Percentage of Total Produc'n	Quantity (Long Tons)	Percentage of Total Produc'n	Amount	Percentage of Total Value
1	Minnesota	34,431,768	62.43	34,249,213	60.07	$61,805,017	57.74
2	Michigan	11,191,430	20.29	12,797,468	22.44	29,008,163	27.09
3	Alabama	4,563,603	8.28	4,766,545	8.36	5,734,371	5.36
4	New York	1,216,672	2.21	1,167,405	2.05	2,938,024	2.74
5	Wisconsin	860,600	1.56	1,152,250	2.02	2,731,574	2.55

Iron-ore mines of the United States that produced more than 50,000 long tons each in 1912.

	Name of Mine	Nearest Town	Variety of Ore	Quantity
2	Raimund No. 1	Lipscomb	Hematite	471,264
1	Woodward No. 1, 2, & 3	Bessemer	Hematite	217,503
3	Songo	Songo	Hematite	173,578
4	Raimund No. 2	Bessemer	Hematite	159,048
5	Greeley	Greeley	Brown Ore	141,577
6	Steinman	Steinman	Hematite	126,695
7	Crudup	Gadsden	Hematite	122,651
8	Ironaton	Ironaton	Brown Ore	93,980
9	Docray	Docray	Brown Ore	77,169
10	Houston	Rickey	Brown Ore	68,763
11	Attalla	Attalla	Hematite	63,604
12	Tannehill	Goethite	Brown Ore	55,512
	Total (12 mines)			1,771,339
	Unspecified* (6 mines)			2,526,390
	Total of mines (23) producing less than 50,000 tons			468,816
	Grand Total			4,766,545

*Includes the product of 6 mines producing over 50,000 tons each, operated by 2 companies, which do not permit the publication of individual statistics.

PIG IRON.

Quantity and value of pig-iron marketed, by the five States in rank, in the United States in 1911 and 1912, with increase and percentage of increase in 1912, in long tons.

State	1911		1912		Increase in 1912		% of Increase in 1912	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Pennsylvania	9,581,109	$136,328,507	12,437,685	$181,569,299	2,856,576	$45,240,792	29.81	33.19
Ohio	5,371,378	73,484,592	7,127,176	93,140,369	1,755,798	19,655,777	32.69	26.75
Illinois	2,036,081	31,152,927	2,806,378	42,828,816	770,297	11,675,889	37.83	37.48
Alabama	1,617,150	17,379,171	1,987,753	21,371,053	370,603	3,991,882	22.92	22.97
New York	1,537,201	23,924,194	1,973,090	28,059,058	435,889	4,134,864	28.36	17.28

LIME.

C. A. ABELE.

ALTHOUGH the production of 1912 was 4.65 per cent greater than that of 1911, the increase was not sufficient to bring the total up to the amount of the 1910 production. The total product of 13 operators in 1912 was 79,957 short tons, an increase over 1911 of 3551 tons, or 4.65 per cent. The value of the product was $297,178, a decrease of $3,609, or 1.20 per cent.

Below is a table presenting some data on the lime production of 1911 and 1912.

Production of lime in 1911 and 1912.

	Number of Operators	Quantity (Short Tons)	Rank of State by Quantity	Value	Rank of State by Value	Average Price Per Ton	Percentage of Total U. S. Value
1911	13	76,406	15	300,787	16	3.94	2.19
1912	13	79,957	14	297,178	17	3.72	2.18
Increase or decrease	------	3,551	------	3,609	------	-------	-----
Percentage	------	4.65	------	1.20	------	-------	-----

The most important use of the lime produced, as in 1911, was for building purposes, more than 65 per cent of the total product being used for this purpose, the remaining portion being used in chemical plants, sugar refineries, tanneries, for fertilizer, or was distributed through dealers.

Shelby county was again the largest producer, having produced 47,859 short tons or over 59 per cent of the total production. The other producers in the order of their rank were Etowah, Blount, Calhoun, and Jefferson counties.

Following is an outline of some of the chemical processes in which lime may be used:

Chemical uses of lime.

E. F. Burchard.

- **Agricultural industry:**
  - As a soil amendment, c, m.[*]
  - As an insecticide, c, m.
  - As a fungicide, c, m.
- **Bleaching industry:**
  - Manufacture of bleaching powder, "Chloride of lime," c.
  - Bleaching and renovating or rags, jute, ramie, and various paper stocks, c, m.
- **Caustic alkali industry:**
  - Manufacture of soda, potash, and ammonia, c.
- **Chemical industries:**
  - Manufacture of ammonia, c.
  - Manufacture of calcium carbide, calcium cyanimid, and calcium nitrate, c.
  - Manufacture of potassium dichromate and sodium dichromate, c.
  - Manufacture of fertilizers, c, m.
  - Manufacture of magnesia, m.
  - Manufacture of acetate of lime, c.
  - Manufacture of wood alcohol, c.
  - Manufacture of bone ash, c, m.
  - Manufacture of calcium carbides, c.
  - Manufacture of calcium-light pencils, c.
  - In refining mercury, c.
  - In dehydrating alcohol, c.
  - In distillation of wood, c.
- **Gas manufacture:**
  - Purification of coal gas and water gas, c, m.
- **Glass manufacture:**
  - Most varieties of glass and glazes, c.
- **Milling industry:**
  - Clarifying grain, c. m.
- **Miscellaneous manufactures:**
  - Rubber, c, m.
  - Glue, c, m.
  - Pottery and porcelain, c, m.
  - Dyeing fabrics, c, m.
  - Polishing material, c, m.
- **Oil, fat, and soap manufacture:**
  - Manufacture of soap, c.
  - Manufacture of glycerine, c.
  - Manufacture of candles, c.
  - Renovating fats, grease, tallow, butter, c, m.
  - Removing the acidity of oils and petroleum, c, m.
  - Lubricating greases, c, m.
- **Paint and varnish manufacture:**
  - Cold-water paint, c, m.
  - Refining linseed oil, c, m.
  - Manufacture of linoleum, c, m.
  - Manufacture of varnish, c, m.
- **Paper industry:**
  - Soda method, c.
  - Sulphite method, m.
  - For strawboard, c, m.
  - As a filler, c, m.
- **Preserving industry:**
  - Preserving eggs, c.
- **Sanitation:**
  - As a disinfectant and deodorizer, c.
  - Purification of water for cities, c.
  - Purification of sewage, c.
- **Smelting industry:**
  - Reduction of iron ores, c, m.
- **Sugar Manufacture:**
  - Beet root, c.
  - Molasses, c.
- **Tanning industry:**
  - Tanning cowhides, c.
  - Tanning goat and kid hides, c, m.
- **Water softening and purifying, c.**

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[*] High calcium lime is indicated by "c," magnesian and dolomitic lime by "m."

MINERAL WATERS.

G. C. MATSON.

RETURNS from Alabama spring owners show that the output of mineral water declined both in quantity and in value during 1912. The total sales decreased from 205,854 gallons, valued at $26,982, in 1911, to 165,678 gallons, valued at $20,435, in 1912, a decline of 19.52 per cent in quantity and 24.26 per cent in value. The average price reported was 12.3 cents a gallon, against 15 cents as the average for 1911. Six new springs were reported during 1912, making a total of 16 springs. About one-half of the total sales of mineral water is used medicinally, and the water at six springs is said to be used for bathing purposes. In addition to the quantity reported as sold, 35,000 gallons were used for the manufacture of soft drinks.

The following 16 springs reported sales:

Alabama Mineral Springs, near Oakhill, Wilcox County.
Bailey Springs, Florence, Lauderdale County.
Bladon Springs, Bladon Springs, Choctaw County.
Blount Springs, Blount Springs, Blount County.
Bromberg Gulf Coast Lithia Springs, Bayou La Batre, Mobile County.
Cherokee Spring, near Citronelle, Mobile County.
Cooks Springs, Cooks Springs, St. Clair County.
Dixie Spring, Dixie Spring, Walker County.
Ingram Lithia Wells, near Ohatchee, Calhoun County.
Livingston Mineral Springs, Livingston, Sumter County.
Luverne Spring, Luverne, Crenshaw County.
MacGregor Spring, Spring Hill, Mobile County.
Matchless Mineral Wells, east of Greenville, Butler County.
Purity Spring, Spring Hill, Mobile County.
Shocco Spring, near Talladega, Talladega County.
White Sulphur Wells, near Jackson, Clarke County.

The following table shows the relative productions, and their respective values, for 1911 and 1912.

Production and value of mineral waters in 1911 and 1912.

	No. of Springs	Quantity Sold (Gallons)	Average Retail Price	Value of Medicinal Waters	Value of Table Waters	Total Value of Mineral Waters	Percentage of Total U. S. Value
1911	10	205,854	$0.15	$20,244	$6,738	$26,982	0.39
1912	16	165,678	0.123	9,610	10,825	20,435	0.30
Increase or decrease	+ 6	+40,176	-----	—10,634	+4,087	—6,547	------
Percentage	------	— 19.52	-----	— 52.53	+60.65	—24.26	------

SAND AND GRAVEL.

THE total production of sand and gravel in the State in 1912 was 852,943 short tons, valued at $268,111, as compared with 677, 894 short tons, valued at $215,413 in 1911, a net increase in quantity of 175,049 short tons, or 25.82 per cent, and an increase of $52,698 or 24.46 per cent in value.

The production of sand was short 11,182 tons from 1911, but the value of the product increased $7,492 or 6.25 per cent. Both the production and the value of gravel increased approximately 50 per cent, which is all the more remarkable when it is noted that chert for road-building was not taken into consideration as in former years.

The following tables give the production, value, and disposition of the sand and gravel produced in 1911 and 1912, and a comparison of the production and value in these years.

Production (in short tons) and value of sand in 1911 and 1912.

	Molding Sand		BuildingSand		Paving Sand		FurnaceSand		Engine Sand		Other Sand		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1911	52,766	$19,432	201,214	$70,284	10,975	$3,635	36,540	$7,738	39,520	$11,106	17,888	$7,563	356,293	$119,758
1912	51,107	25,284	205,498	66,586	37,801	14,497	-----	-----	45,000	13,300	15,705	7,083	355,111	127,250
Increase or decrease	—1,659	+5,852	+4,284	—3,698	+26,826	+10,862	-----	-----	+5,480	+2,194	—2,183	— 480	—11,182	+ 7,492
Percentage	— 3.18	+30.11	+ 2.08	— 5.26	+244.43	+298.82	-----	-----	+13.86	+19.75	—12.20	—6.34	— 1.26	+ 6.25

Production of Sand and Gravel in 1911 and 1912.

	Sand		Gravel		Total		Total U. S. Value Percentage of
	Quantity	Value	Quantity	Value	Quantity	Value	
1911	356,293	$119,758	321,601	$95,655	677,894	$215,418	1.018
1912	345,111	127,250	497,882	140,861	852,943	268,111	1.16
Increase or decrease	—11,182	+ 7,492	+176,281	+45,206	+175,049	+52,698	------
Percentage	— 3.14	+ 6.25	+ 54.79	+ 47.25	+ 25.82	+ 24.46	------

STONE.

E. F. BURCHARD.

THE figures presented in the following report have to do with the stone produced and sold by the quarrymen and include only such manufactured product as is put on the market by the quarrymen themselves. This applies especially to rough and dressed building stone, dressed monumental stone, crushed stone, flagstone, curbstone, and paving block. The value given to this manufactured product is the price received by the producer, free on board at point of shipment, and includes therefore the cost of labor necessary to dress the stone. The stone reported as sold rough includes stone sold as rough stock to monumental works, and to cut-stone contractors for building purposes; stone sold as riprap, rubble, and flux; and includes the value of only such labor as is required to get the stone out of the quarry in the shape required by the purchaser. The value given to this stone is the price received by the quarryman free on board at point of shipment. In case the stone is sold to local trade the value is given as the quarryman sells the material, generally at the quarry, but in some cases delivered, if this is done by the producer. In some instances a long haul to market or to the railroad increases the cost of the material, and therefore of the selling price.

PRODUCTION.

C. A. ABELE.

Alabama produces commercially only three kinds of stone, namely, limestone, marble, and sandstone. Of these, the limestone production and value reached the largest proportions, though the value of the limestone produced fell below the figures established in 1910 and 1911. Marble was the only stone whose production showed an increase over that of 1911. The value of the sandstone produced in 1912 was approximately 60 per cent less than the value of the 1911 product.

Below is a table giving the value of the limestone produced in the last five years, from 1908 to 1912, inclusive.

Value of stone production from 1908 to 1912.

Kind	1908	1909	1910	1911	1912
Limestone	$479,730	$700,642	$714,516	$561,798	$531,085
Sandstone	34,099	77,327	109,068	73,195	27,596
Total	513,829	777,969	823,579	634,983	558,681

LIMESTONE.

The most important use of the limestone produced in Alabama in 1912, as in 1911, was blast furnace flux, while riprap, road-making, and crushed stone for concrete follow in the order named. The limestone burned into lime or used in the manufacture of Portland cement is not taken account of here, but is included in the value of each of the finished products in whose manufacture it was used.

As thus limited, the total value of limestone produced in 1912 was $531,085, as compared with $561,748 in 1911, a decrease of $30,713 or 5.46 per cent.

The values of the limestone produced in 1911 and 1912, classified according to the uses of the stone, are given in the following table:

Value of Limestone produced in 1911 and 1912.

Use	1911	1912	Increase or Decrease	Percentage
Paving	$170	$15,700	+ 15,530	—
Riprap	10,459	81,361	+ 70,902	677.90
Roadmaking	37,511	54,270	+ 16,759	44.67
Railroad Ballast	----------	14,093	+ 14,093	—
Concrete	23,077	26,235	+ 3,158	13.68
Flux	458,356	339,166	— 119,190	26.00
Other uses	308	60	— 248	80.52
Total	561,798	531,085	— 30,713	5.46
Percentage of total U. S. value	1.66	1.44	----------	----------

LIMESTONE FOR BUILDING PURPOSES.

EUGENE A. SMITH.

From the tables above it will be seen that by far the largest part of the limestone for other purposes than lime burning produced in Alabama 1911-1912, has been for flux rock in the iron furnaces. Crushed stone for road making and riprap follow next, and then dressed building stone.

The preparation of cut stone for building purposes in Alabama, while on the increase, is not yet what it should be. Practically all of this material comes from the quarries in the subcarboniferous limestone of the Tennessee Valley, the most important quarries being at Rockwood in Franklin County, operated by Foster-Creighton-Gould Co., of Nashville. This stone is quite similar in appearance, composition, and other qualities to the Indiana stone, and so far as experience in the use of the stone from the two localities in the buildings of the University of Alabama goes, the Alabama stone holds its own under influence of the weather better than does the Indiana stone. Stone steps, door sills, and window sills, buttress caps, etc., of the Alabama stone put in place in 1885 show practically no deterioration in color and wear under foot, and in crumbling and roughening under the influence of the weather, which cannot be said of some portions of the Indiana stone used in buildings erected in 1909-10. The Rockwood quarries have most modern and approved methods of machinery for sawing the stone and handling it in transit to the mills and elsewhere. The stone is of massive formation, of great thickness and extent. Blocks weighing as much as 25 tons, without crack or flaw, are not infrequently quarried, the size of the blocks being practically limited only by the capacity of the hoisting machinery.

The Oolitic variety is most extensively used for building and monumental work. It is of light gray color, uniform grain, and homogeneous texture. It possesses a quality of cheapness, it can be cut to any design required, and is at the same time strong and durable.

At the present time the business at this quarry is confined to the furnishing of rough and sawed stone to the cut stone contractor or dealer.

With the installing of adequate machinery at the quarry for doing the finished work, there should never be any longer any reason for going outside of the State for this quality of stone. Already the material has been very extensively used in public buildings in Mississippi, Tennessee, as well as in Alabama. The only reason why it was not used in the recently erected buildings at the University of Alabama was that at the time these building contracts were let, the quarries furnished only the rough sawn stone and there was not in Alabama any establishment adequately equipped for the dressing of the stone in the quantity needed.

MARBLE.

EUGENE A. SMITH.

The marble of Alabama is of two kinds, crystalline or true marble and non-crystalline.

The crystalline or statuary marble occurs mainly in a narrow valley along the western border of the metamorphic area, extending from Marble Valley in Coosa County, through Talladega into Calhoun. The length of the marble belt through Coosa and Talladega counties is about 50 miles. The width of the valley carrying the marble as a rule is from one quarter to one-half mile, widening in places to a mile and a quarter, for example in the neighborhood of Sylacauga.

The quarries longest known are Gantt's and Herd's near Sylacauga, Nix's near Sycamore, and Taylor's and McKenzie's near Taylor's Mill East of Talladega. From all these marble was quarried before the civil war.

During 1912, only 3 establishments had reported any marble production, viz.: The Alabama Marble Co., at Gantt's Quarry near Sylacauga, the Alabama-Carara Marble Co., near Talladega, and the Moretti-Harrah Marble Co., Sylacauga. Two other companies, however, have made some rather extensive developments and will no doubt report some production later. These are the Eureka Marble Co. (Bishop's) near Talladega Springs; the Alabama Marble Quarries of the Scott Brothers, near Sycamore.

The plant of the Alabama Marble Company at Gantt's Quarry was destroyed by fire in December, 1910, and it was not until the middle of August, 1911, that the rebuilding was completed and production begun.

I think it is fairly safe to say that on the whole the marble from this quarry and immediate vicinity is of the highest grade of commercial white marble now on the market and obtainable in large quantity. There are small quantities of marble produced both in Italy and Vermont that are somewhat freer from coloring matter than the best grades that can be produced in Alabama in any quantity. But on the other hand, the poorest grades in Alabama greatly surpass the poorest grades produced elsewhere, so that the average of the Alabama deposit is probably somewhat higher than that of any other so far developed, not excluding even the marble from the Carara district in Italy. The marble from this State (Gantt's Quarry) has now a well established reputation and has been used in more than 150 important buildings throughout the United States.

It can be seen in the galleries of the National Museum in Washington.

A beautiful quality of variegated limestone or marble—red, pink and white—belonging probably to the Cambrian formation, occurs in Shelby County a mile or two south of Shelby Springs station on the L. & N. railroad, and extending thence southwest for a mile or two. Nothing but prospecting work has been done on this marble. The Trenton limestone in the Appalachian valleys, particularly Jones Valley below Bessemer, contains marble similar to that quarried in the vicinity of Knoxville, Tenn. Also at Pratt's ferry on the Cahaba River in Bibb County a quarry was for many years worked in this formation and turned out a very beautiful quality of marble varying in color from gray through pink, red and brown shades.

A black marble which is exceedingly promising, has been reported and some development work done near Anniston, and at Piedmont, Calhoun County, and some very handsome specimens of cave onyx have been obtained from near Kymulga in Talladega County.

In the Coastal Plain the St. Stephens limestone of the Tertiary holds ledges of hard, almost crystalline rock capable of taking good polish. The colors vary from nearly white, through shades of yellowish into red, and it would make a handsome decorative marble, especially for inside work.

Other limestone formations, such as the Subcarboniferous and the Knox Dolomite, could in places be drawn upon for marble.

It is possible to publish only the total value of the marble produced in the State in 1912, since a classification of the product according to its uses would necessitate the publication of confidential figures. The total value of the marble produced, the product of three operators, was $283,619 or 3.64 per cent of the total United States value.

The greater portion of the product was used for interior decoration.

SANDSTONE.

The production of sandstone in 1912 suffered a decline of nearly 60 per cent from that of 1911. In fact, so great was the decrease in the production of this stone that it is possible to publish only the total value of the stone produced in order not to divulge figures of single producers given the Survey in confidence.

Rubble, riprap, and crushed stone, and also an insignificant amount of ganister were produced, but in no case did the 1912 production equal that of 1911, the decrease ranging from 34 per cent to 99 per cent.

The total value of the 1913 production was $27,596 as compared with $73,195 in 1911, or a decrease of $42,599 or 58.20 per cent.

SUMMARY.

BECAUSE of the difference in the units of measurement employed in the various branches of the mineral industry, a summation of the production of the year can include only the values of the products. It is also to be noted that a simple summation of all the values of the minerals or mineral products listed in this pamphlet would give a value much in excess of the true value, since in many cases, as, for instance, coal and coke, and iron ore and pig iron and steel, the second product is directly a product of the first, and the value of the first is included in that of the second. To give the values of both as a part of the total would be to repeat, in a measure, at least a partial value of the first or raw product, and would give an erroneous result.

As the Survey has not however, the figures upon which to base an estimate as to the percentage of each product which was used in the manufacture of some other product, the summation of the mineral production of the State, as given here, will be a simple summation of the values reached by the individual branches of the industry.

According to this rather unsatisfactory manner of summation, which does not include the value of the steel produced, the value of the 1912 mineral production and ultimate products was $60,141,793, as compared with $52,772,951 in 1911, an increase of $7,368,842 or 13.96 per cent. This value was still, however, lower than that of 1910 by $3,066,152 or 4,86 per cent.

In 1912 pig iron was the most valuable product, the others being in the order of their value, coal, coke, iron ore, clay products, cement, limestone, lime, sand and gravel, marble, and miscellaneous, including bauxite, clay, sandstone, graphite, mineral waters, gold and silver, mica, and abrasives.

Below is a tabular presentation of the value of the mineral productions of 1910, 1911 and 1912.

Total value of the mineral production and products in Alabama in 1910, 1911, and 1912.

Year.	Value.
1910	$63,207,945
1911	52,772,951
1912	60,141,793

A far truer conception of the relative production of 1910, 1911, and 1912 may be obtained by taking the production returns of each branch of the industry, irrespective of the varieties of units of measurement used, forming a percentage for 1911 and 1912 based on the production of 1910, weighting this percentage by the value of the output, thus preparing an index number of each branch.

Proceeding in this manner, the following results are deduced:

Percentage of the production of mineral products (raw and finished) in 1911 and 1912, using the production of 1910 as a base.

Year.	Percentage.
1910	100.0
1911	88.6
1912	84.4

PROBABLE FUTURE PRODUCTION.

The following minerals have been produced in Alabama in past years, but no production was reported for 1912; Fuller's Earth, Manganese Ore, Pyrite, Mineral Paints, Petroleum, Phosphate Rock, and Quartz. Since all these are known to occur in some quantity and of a quality to make them of commercial value, the production may be resumed at any time.

Among the probable productions in the near future, are natural gas and petroleum, onyx marble, turquoise and other minerals noticed in the Index to the Mineral Resources of Alabama a publication of the State Geological Survey.

Natural gas under pressure of 630 pounds has been obtained from several wells in Fayette and Walker Counties, and smaller quantities under less pressure have been obtained near Huntsville and elsewhere.

A Report with map on the Fayette County Gas Field has been published by the survey during the year. No commercial production has yet been reported.

GEOLOGICAL SURVEY OF ALABAMA

EUGENE ALLEN SMITH, *State Geologist*

BULLETIN No. 15.

STATISTICS OF THE MINERAL PRODUCTION OF ALABAMA FOR 1913

COMPILED FROM MINERAL RESOURCES OF THE
UNITED STATES

By
CHARLES ARTHUR ABELE

UNIVERSITY, ALABAMA
1914

PRESS
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ALABAMA

LETTER OF TRANSMITTAL.

UNIVERSITY, ALA., December, 1914.

HON. EMMET O'NEAL,
Governor of Alabama,
Montgomery, Ala.

SIR:—I have the honor to transmit herewith the manuscript of a Report on the Mineral Production of Alabama for the year 1913, with the request that it be printed as Bulletin No. 15 of the Geological Survey of Alabama.

Very respectfully,
EUGENE A. SMITH,
State Geologist.

GEOLOGICAL CORPS.

Eugene Allen Smith, Ph. D.	State Geologist
William F. Prouty, Ph. D.	Chief Assistant
S. J. Lloyd, Ph. D.	Assistant
Robert S. Hodges	Chemist
Herbert H. Smith	Curator of Museum
Roland M. Harper, Ph. D.	Botanist
George N. Brewer	Field Assistant
A. T. Donoho	Stenographer

RIVER GAGE HEIGHT OBSERVERS.

C. J. Stowe	Jackson's Gap, Tallapoosa River
J. E. Whitehead	Riverside, Coosa River
S. T. Willard	Beck, Conecuh River
Ed. Bullen	Red Bay, Big Bear Creek
E. Cummings	Wedowee, Little Tallapoosa River

From the records of daily observations of the gage readings at these places when extended through sufficient time, the calculations of available horsepower to be obtained from the different streams is made.

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PREFACE.

The statistics of all the minerals included in the following pages have been collected in cooperation with the United States Geological Survey, and have been compiled from advance chapters of the *Mineral Resources of the United States*, a publication of the Federal Survey.

The introductory and general matter in each of these articles has either been taken without change from the U. S. advance chapters or has been rearranged or condensed from these chapters, or entirely rewritten to suit it for our present purposes. In each case credit is given to the author.

INTRODUCTION.

By E. W. Parker, Statistician, U. S. G. S.

With iron ore considered as the basis of iron production, Alabama ranks eighteenth among all the States in the value of its mineral products, and second among the States south of Mason and Dixon's line and Ohio River. If pig iron were taken as the basis of iron production, Alabama would rank about fifteenth among all the States, but would maintain the position it now holds among the Southern States. West Virginia, with its great production of mineral fuel—coal, petroleum, and natural gas—is the premier mineral producer among the Southern States. Alabama is not distinguished as the leading producer in any important mineral substance, but it ranks third in the production of iron ore, fifth in the production of pig iron, second in quantity and third in value in the production of coke, and sixth in quantity and fifth in value as a producer of coal. Considerable progress has been made in the development of the clay-working and quarrying industries, but these resources have not been exploited to the same extent as those of coal and iron.

The rise of Alabama as a mining and industrial Commonwealth had its beginning in the last quarter of the nineteenth century following the development in 1882 of the extensive deposits of iron ore in the vicinity of Birmingham and contiguous to the already partially known and developed coal fields. The boom and speculative fever which followed was one of the most spectacular incidents in the industrial development of the United States, paralleled only by the rushes which followed Marshall's discovery of gold in California, the exploitation of the Comstock lode in Nevada, and the later rush to the Alaskan gold fields. The speculative fever reached its climax in 1885, and was followed by a period of relapse and liquidation which lasted two years. There was beneath the Birmingham craze, however a substantial foundation for legitimate industrial development, and after the bursting of the original bubble there has followed more than a quarter of a century of steady healthful growth. The iron ores of Alabama, while inferior to those of Lake Superior, have a compensating advantage in the deposits of good coking coal, and of the limestone requisite for fluxing in the immediate vicinity, as the result of which Birmingham, the Pittsburgh of the South, can manufacture pig iron cheaper than any other district in the world. The iron ores are principally non-Bessemer hematites, and steel is produced chiefly by the open-hearth process. Prior to 1882 when the boom began, the coal production of Alabama had not amounted to as much as half a million tons in any one year. In 1885 it was nearly 2,500,000 tons, but in the collapse of 1886 that followed it decreased to 1,800,000. Since 1886 it has shown an almost unbroken series of annual increases in the production and reached its maximum of 17,678,522 tons in 1913, an increase of more than 1,500,000 tons over 1912, and exceeded, by approximately the same quantity, the previous maximum record made in 1910. The value of the coal product of Alabama is approximately two-thirds that of the total mineral output, and amounted in 1913 to $23,083,724.

In 1882 Alabama produced about 100,000 long tons of pig iron. In 1913 the marketed production of pig iron in Alabama amounted to 1,924,762 long tons, valued at $23,242.374, a slight decrease in quantity from 1912 and an increase in value of nearly $2,000,000. The value of the pig iron produced in Alabama in both 1912 and 1913 was slightly in excess of the value of the coal mined. Although the production of pig iron in 1913 was less than in 1912, there was an increase in the production of iron ore from 4,776,545 tons in 1912, valued at $5,734,371, to 5,333,218 long tons, valued at $6,648,569, in 1913. The value of this iron-ore production, not the value of the pig iron, is used in making up the total value of the mineral products of the State.

The coke production of Alabama increased from 2,975,489 short tons, valued at $8,098,412, in 1912 to 3,323,664 short tons, valued at $9,627,170, in 1913. The increase in the production of iron ore and in the manufacture of coke with the decreased sales of pig iron, indicate that some of the ore and of the coke was sent to furnaces outside of the State, although in addition to the actual marketed production of pig iron there was an increase in stock carried over to January 1, 1914, as compared with stocks on hand January 1, 1913.

The total value of the mineral production of Alabama, exclusive of the value of the pig iron and including the value of the iron ores, was $34,660,545 in 1913, compared with $30,641,983 in 1912, of which, as already stated, approximately two-thirds is represented by the output of the coal mines. Nearly one-fifth of the total value was contributed by the iron mines. The increase in 1913 over 1912 was $4,018,562, or 13 per cent. The principal coal-producing counties are Jefferson, Walker, Bibb, and Tuscaloosa in the order named. The principal iron ore counties are Jefferson, Tuscaloosa, Etowah and Franklin. The iron-making industry is centered in Birmingham and vicinity. The combined value of the pig iron and coke made in Alabama approximates $33,000,000. These values are not included in the total as they are represented in the value of the iron ore and the coal produced. The clay-working industries yielded products in 1913 valued at $2,091,581, against $1,935,179 in 1912, the principal part of which is from the manufacture of common brick. This does not include the value of raw clay sold, which in 1913 amounted to $53,419. The center of the clay-working industry is in Jefferson County, and Birmingham furnishes the principal market. Vitrified, front, and fire brick represent a value approximating that of common brick alone, and the total output of the brickyards makes up nearly 80 per cent of the State's total clay products. All of the fire brick produced in the State is reported from Jefferson County and all of the vitrified brick is from Jefferson and St. Clair counties. Clay pits for the manufacture of common brick have been opened in one or more places in 38 different counties. The quarry products, the larger part of which is limestone, were valued in 1913 at $1,285,944, an increase of more than 50 per cent from $842,300 in 1912. The increased production in 1913 was in the output of limestone for flux and concrete work, sandstone for use in Government improvements on Warrior River, and the production of marble. Two-thirds of the total value of the stone production is limestone. The most important use of the limestone is for blast furnace flux, with riprap, road making, and crushed stone following in the order named. Little of the Alabama limestone is used for building at the present time, but in the opinion of Dr. Eugene A. Smith this use is on the increase and is due to the development of an oolitic limestone similar in appearance and composition to the Indiana stone. This stone is of light-gray color, uniform grain, and homogeneous texture. It possesses the quality of cheapness and can be cut to any design required. Marble holds second place in the value of the quarry products, a beautiful white marble occurring in Coosa and Talladega counties being used extensively for building, and black marble which gives promise of future development has been prospected near Anniston. The cement production of Alabama amounted in 1913 to 823,246 barrels, valued at $685,422, against 726,688 barrels, valued at $608,620, in 1912. The lime production is not included in that of the limestone, and amounted to 75,468 short tons, valued at $290,394 in 1913, a decrease from 79,957 short tons, valued at $297,178, in 1912. Alabama produces a small quantity of gold and silver, and other minor products are bauxite, graphite, mica, millstones, mineral paints (natural pigments), mineral waters, natural gas, and sand and gravel.

In the following table is presented a comparison of the mineral output of Alabama in 1912 and 1913. As stated above, the total does not include the value of pig iron nor that of coke, but it does include the value of the coal made into coke and of the iron ore sold or used:

Mineral production of Alabama in 1912 and 1913.

PRODUCT	1912				1913			
	Raw		Derived		Raw		Derived	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Bauxite long tons	14,178	$60,254			(*)	(*)		
Cement, barrels			726,688	$608,620			823,246	$685,422
Clay products, short tons	48,052	†38,414		1,985,179	49,901	†$58,419		2,091,581
Coal, short tons	16,100,600	20,829,252			17,678,522	23,083,724		
Coke, short tons			2,975,489	†8,098,412			3,323,664	†9,627,170
Gold, fine ounces (troy)			809	16,724			537	11,094
Graphite, crystalline, pounds	(*)	(*)			2,020,910	87,336		
Iron ore, long tons	4,776,545	5,734,371			5,333,218	6,648,569		
Iron, pig, long tons			1,987,753	†21,371,053			1,924,762	† 23,242,374
Lime, short tons			79,957	297,178			75,468	290,394
Mica								(*)
Millstones				(*)				(*)
Mineral paints, natural pigments, short tons							(*)	(*)
Mineral waters, gallons sold	165,678	20,435			169,687	19,343		
Natural gas		(*)				(*)		
Sand and gravel, short tons	852,943	268,111			1,405,068	398,088		
Silver, fine ounces (troy)			168	103			117	71
Stone		(‡)		‡842,300		(‡)		‡ 1,285,944
Miscellaneous		(‡)		‡29,456		46,618		12,361
Total value, eliminating duplications	$30,641,983				$34,660,545			

*Value included under "Miscellaneous." †Value not included in total value. ‡Raw product included under derived product.

STATISTICS OF THE MINERAL PRODUCTION OF ALABAMA FOR 1913.

ABRASIVES.

EUGENE A. SMITH.

ALABAMA'S production of abrasives is at present limited to a small number of millstones quarried and made at Dutton, Jackson County; there are, however, several materials in different parts of the State which are sufficiently promising to be worth investigation and thorough testing; the nature and locality of these deposits were treated in Bulletin No. 13, which see.

BARYTES.

So far as known, no barytes has been produced from Alabama mines since 1906. There are some deposits which probably could be worked in Calhoun, Etowah, and St. Clair Counties, in the northeastern part of the State, and in Bibb County, near the center. The residual deposits so far worked are associated with the Chickamauga ("Pelham") limestone, of Ordovician age, and the Knox dolomite, of Cambrian and Ordovician age. They seem to be localized along lines of folding and faulting of the rocks, particularly along the eastern side of the Appalachian fold. The barytes probably occured originally as veins and replacements along fissured or fractured dolomite. Solution of the dolomite has left the insoluble barium sulphate in nodules and bowlders in the residual clay.

BAUXITE.

The production of bauxite in Alabama for 1913 was limited to one producer, which accounts for the decrease and also for the joining of the Alabama and Georgia totals.

The following table gives the production and value of bauxite from 1889 to 1913, inclusive:

Production of bauxite in the United States, 1889-1913, by States, in long tons

Year	Georgia	Alabama	Arkansas	Total	Value
1889	728	....	....	728	$2,366
1890	1,844	....	....	1,844	6,012
1891	3,301	292	....	3,593	11,675
1892	5,110	5,408	....	10,518	34,183
1893	2,415	6,764	....	9,179	29,507
1894	2,050	9,016	....	11,066	35,818
1895	3,756	13,313	....	17,069	44,000
1896	7,313	11,051	....	18,364	47,338
1897	7,507	13,083	....	20,590	57,652
1898	....	....	....	25,149	75,437
1899	15,736	14,499	5,045	35,280	125,598
1900	19,739		3,445	23,184	89,676
1901	18,038		867	18,905	79,914
1902	22,677		4,645	27,322	120,366
1903	22,374		25,713	48,087	171,306
1904	21,913		25,748	47,661	235,704
1905	15,173		32,956	48,129	240,292
1906	25,065		50,267	75,332	368,311
1907	....		....	*97,776	480,330
1908	14,464		*37,703	52,167	263,968
1909	22,227		*106,874	129,101	679,447
1910	33,096		*115,836	148,932	716,258
1911	30,170		*125,448	155,618	750,649
1912	19,587	14,173	*126,105	159,865	768,932
1913	27,409		*182,832	210,241	997,698

*Production of Tennessee included.

For an outline of the uses of bauxite, see Bulletin No. 13.

CEMENT.

EUGENE A. SMITH.
E. F. BURCHARD.

PUZZOLAN OR SLAG CEMENT.

DURING the past six years only one establishment in Alabama has been engaged in the manufacture of slag cement, using the material from the furnaces about Birmingham. The production is included in the returns for Portland cement and cannot be given separately.

PORTLAND CEMENT.

RESOURCES.

Alabama contains large supplies of limestone, chalk, clay and shale well adapted for Portland Cement manufacture, and widely distributed throughout the State. Coal and labor are abundant and cheap, transportation facilities are excellent, and many of the best limestone and chalk localities are situated on navigable rivers, giving ready access and cheap water transportation to Galveston, New Orleans, Mobile, Charleston, and other ports of the Gulf and Atlantic Coasts. This advantage of location will be immensely increased with the opening of the Panama Canal for cement plants located in Alabama will be more than a thousand miles nearer to the Isthmus than their nearest possible competitors

The limestones and shales of the northern part of the State lie so close to each other, and above all so close to the great coal mines which must supply the fuel, that the establishment of Portland Cement plants near the coal mines would give to this industry in Alabama the same advantages which the proximity of the iron ore, the coal, and the stone has given to the iron industry, and which has placed our State beyond competition.

As a Portland cement mixture, ready for burning, consists approximately of 75 per cent. lime carbonate and 25 per cent. of clayey matter, the material furnishing the lime carbonate is necessarily of more economic importance than that from which the silica and alumina are derived. In consequence, a Portland cement plant is usually located in the immediate vicinity of a suitable limestone, while the clay or shale required to complete the mixture may be brought some distance.

The limestone formations in North Alabama which can supply the stone adapted for use in cement manufacture are the Trenton or Pelham limestone and the Bangor or Subcarboniferous. In close proximity to both these limestone formations are the shales of the Clinton, Subcarboniferous and Coal Measures.

At the present time there are two cement plants in North Alabama, namely, the Standard Portland Cement Co., located at Leeds in Jefferson County, and the Atlantic & Gulf Portland Cement Co., located at Ragland in St. Clair County. Both of these plants make use of the hard Trenton limestone, and the Standard Cement Co., according to Burchard of the U. S. Geological Survey, uses the shale of the Clinton formation whilst the Ragland Company makes use of the shales of the Coal Measures. Up to the present time no establishment is utilizing the Bangor limestone.

In Middle Alabama the soft, chalky Cretaceous limestone of the Selma Chalk, is the material utilized by the Alabama Portland Cement Co., at Spocari, near Demopolis. The same Company makes use of residual clays overlying and derived from the weathering of the Selma Chalk. During 1913 there was no production reported from the Demopolis plant.

In Southern Alabama the St. Stephens limestone outcropping east and west across the State, furnishes excellent material for Portland Cement manufacture, using either residual clays from decomposition of the limestone, or the clays of the Grand Gulf formation which are almost everywhere in close proximity to the limestone.

The following table summarizes the number of active plants in the United States, and the production of puzzolan cement during the last five years:

Statistics of the puzzolan cement industry, 1909-1913.

	1909	1910	1911	1912	1913
Number of plants reporting production:					
Alabama	1	1	1	1	1
New York*	....	....	1	1	1
Ohio	2	2	1	1	1
Pennsylvania	1	1	1	1	1
Total	4	4	4	4	4
Production in barrels of 330 pounds	160,646	95,951	93,280	91,864	107,313
Value of production	$99,453	$63,286	$77,786	$77,363	$97,663

*Includes production of Collos cement in 1911, 1912, and 1913.

Owing to the fact that there was in Alabama in 1913 only one producer of puzzolan cement, and not more than two operating plants in the Portland cement industry, it is necessary to combine the productions of both industries in order to avoid publishing figures which were given the Survey in confidence. The tabular results of such a combination are, however, necessarily inconsistent and not to be taken too literally, since the weights per barrel of the two kinds of cement vary.

The total quantity of Portland and puzzolan cement produced in Alabama in 1913 was 823,246 barrels, valued at $685,422 as compared with 726,688 barrels in 1912, valued at $608,620, or an increase in the production of 96,588 barrels, or 13.3 per cent, giving an increase in value of $76,802, or 12.6 per cent.

The percentages of increase in quantity and value are notably less than in 1912.

Below are presented in tabular form the foregoing figures.

Production and value of cement (including puzzolan and Portland) in Alabama in 1912 and 1913.

	No. of Producers	Quantity (Bbls.	Value	Percentage of total U. S. Value
1912	3	726,688	$608,620	0.91
1913	3	823,246	685,422	0.74
Increase	....	96,558	76,802	....
Percentage increase	....	13.3	12.6	....

CLAY AND CLAY PRODUCTS.

JEFFERSON MIDDLETON AND EUGENE A. SMITH.

CLAY.

CLAY available for the manufacture of clay products is one of the most widely spread of our minerals. Clay miners are usually also the manufacturers of the lower-grade clays, but as the higher grades of ware are reached, the rule is that fewer and fewer manufacturers are also miners, until in the highest grades of ware the rule is that the manufacturer is not the miner of the clays that he uses. The figures given in the following tables represent clay that is mined and not manufactured by the miner, but is sold as clay. The clay thus sold is small in quantity compared with that consumed and includes mainly clay used for refractory products.

The total quantity of clay mined in Alabama and sold as such in 1913 was 49,901 short tons, valued at $53,419. This was an increase in quantity of 6,849 tons, or 15.91 per cent, and of $20,005, or 59.87 per cent in value over 1912. While some miscellaneous clay was produced in 1913, fire clay was the only kind of which the figures of production are available for publication.

Below is a table giving the production and value of clay mined and sold in Alabama from 1909 to 1913 inclusive, and a comparison of the production of 1912 and 1913.

Production of clay in Alabama from 1908 to 1913 inclusive, and a comparison of the production in 1912 and 1913.

YEAR	Fire Clay		Miscellaneous Clay		Total	
	Quantity Short Tons	Value	Quantity Short Tons	Value	Quantity Short Tons	Value
1908	68,289	$48,983	24,000	$12,000	92,289	$60,988
1909	45,137	35,345	18,271	5,587	63,408	40,982
1910	54,482	32,395	20,600	5,650	75,082	38,045
1911	35,208	29,909	....	....	35,208	29,909
1912	38,552	31,414	4,500	2,000	43,052	33,414
1913	49,901	53,269	*	*	49,901	53,419
Increase 1913	11,049	21,855	....	....	6,849	20,005
Percentage of Increase	28.66	69.56	....	....	15.91	59.87

*Not divulged but included in total.

In 1912 the average value of fire clay was $0.81 per short ton and the fire clay production of Alabama represented 1.33 of the total value of the United States production. In 1913 the average value of Alabama fire clay was $1.07 per short ton, and the value of the Alabama product was 2.06 per cent of the total value of the fire clay produced in the United States.

CLAY WORKING INDUSTRIES.

ALABAMA is rich in clays, but its rank as a clay-working State is not high. In 1913 it was sixteenth among the States, with products valued at $2,091,581, or 1.15 per cent of the total for the country. This was an increase over 1912 of $156,402, or 8.08 per cent. In 1913 Alabama was ninth in the production and value of vitrified brick, and ninth in production and eleventh in value of fire brick. The principal product is common brick, valued in 1913 at $730,148, and representing 34.91 per cent of the value of all of Alabama's clay products in that year. Front brick, fireproofing, and tile, not drain, were reported to the value of $258,130, so that the structural materials represent nearly one-half of Alabama's clay products in 1913. The engineering products, vitrified paving brick, draintile, sewer pipe, and fire brick were reported to the value of $1,057,059, or more than 50 per cent of the total. Pottery clays are abundant in the State, but this branch of the industry has not been developed extensively, the value of pottery production in 1913, being only $20,158.

Jefferson County is the principal clay-working county, reporting a production valued at $1,313,432, or 62.8 per cent of the total value for 1913, an increase of $178,093 over 1912. No pottery was reported from this county. All of the fire brick produced in the State comes from Jefferson County, and fire brick is its principal product. Vitrified brick was reported only from Jefferson and St. Clair counties, the former being the leading county with 22,710,000 brick, valued at $339,615. The leading counties in the value of common brick in 1913 were, in the order of their importance, Montgomery, Talladega and Jefferson.

Clay products of Alabama, 1909-1913.

Product	1909	1910	1911	1912	1913
Brick:					
Common—					
Quantity	146,180,000	135,785,000	129,694,000	136,989,000	130,923,000
Value	$799,693	$746,961	$708,903	$759,409	$780,148
Average per M	$5.47	$5.50	$5.47	$5.54	$5.58
Vitrified—					
Quantity	20,444,000	19,772,000	21,444,000	26,480,000	24,183,000
Value	$262,376	$236,516	$246,707	$353,303	$361,722
Average per M	$12.83	$11.96	$11.50	$13.34	$14.96
Front—					
Quantity	(*)	(*)	9,169,000	10,629,000	(*)
Value	(*)	(*)	$128,403	$132,033	(*)
Average per M	$16.19	$15.96	$14.00	$12.42	$15.29
Fancy, value	(*)	....	(*)	(*)	....
Fire, value	$196,887	$163,672	$193,375	$240,434	(*)
Draintile, value	(*)	$3,773	$3,777	$5,465	$10,302
Sewer pipe, value	(*)	(*)	(*)	(*)	(*)
Fireproofing, value	(*)	(*)	(*)	(*)	(*)
Tile, not drain, value	....	....	....	....	(*)
Pottery:					
Red earthenware, value	$11,886	$3,475	$11,243	$10,990	$11,164
Stoneware and yellow and Rockingham ware, value	$24,453	$16,371	*$14,753	$11,223	$8,994
Miscellaneous, value	$404,832	$496,791	$639,941	$422,322	$968,751
Total value	$1,700,127	$1,667,559	$1,947,102	$1,935,179	$2,091,581
Number of active firms reporting	100	87	82	74	68
Rank of State	22	22	17	17	16

*Included in "Miscellaneous."

BRICK AND TILE.

THE total production of common brick in Alabama in 1913 was 130,923 M, valued at $730,148. This, as compared with the 1912 production, represents a decrease in both quantity and value, of 6,066 M, or 4.43 per cent, and of $29,261 or 3.85 per cent.

In the case of vitrified brick there was a decrease in quantity of 2,297 M, or 8.67 per cent. but an increase in value of $8,419, or 2.38 per cent. The other kinds of brick, including front, fire, fancy, sewer pipe, fire proofing and silica brick (produced by less than three manufacturers, and individual production therefore not available for publication), show an increase in value of $73,962, or 8.26 per cent.

The following tables give a review of the brick and tile industry in Alabama for 1912 and 1913:

Production of brick and tile in Alabama in 1913, not including pottery products.

Kind	Quantity per Thousand	Value	Average Value per Thousand	Percentage of total value of brick and tile	Percentage of total U. S. value
Common brick	130,923	$730,148	$5.58	35.25	1.46
Vitrified Brick	24,183	361,722	14.96	17.46	2.98
Drain Tile	....	10,802	....	0.52	0.12
Miscellaneous	....	*968,751	....	46.77	....
Total	....	$2,071,423	....	100.00	1.97

*Includes front brick, fire brick, fancy brick, sewer pipe, fire-proofing, and silica brick.

Brick and tile production in 1912 and 1913 compared.

Kind	1912			1913			Increase or Decrease in Value	Percentage
	Quantity M	Value	Average Price	Quantity M	Value	Average Price		
Common Brick	136,989	$759,409	$5.54	130,923	$730,148	$5.58	—$29,261	3.85
Vitrified Brick	26,480	353,303	13.34	24,183	361,722	14.96	+ †8,419	2.38
Front Brick	10,629	132,033	12.42	*	*	15.29	....	......
Fire Brick	....	240,434	....	*	....	....	....	......
Drain Tile	....	5,465	....	....	10,802	....	+ †5,337	97.66
Miscellaneous	....	*422,322	....	....	†968,751	....	....	......

*Includes fancy brick, sewer pipe, fire proofing, and silica brick.

†Includes front brick, fire brick, fancy brick, sewer pipe, fire proofing, and silica brick.

POTTERIES.

THE pottery industry of Alabama is of relatively small importance, as only the commoner and coarser grades of ware are produced, and most of this for local trade only.

Production was reported for 1913 by 9 operators, a decrease of 6. The output was valued at $20,158, a decrease of $2,055, or 9.25 per cent. The products consisted of red earthen ware and stone ware only. There were five idle potteries in Alabama in 1913. The rank of Alabama in this industry for 1913 is 18.

The following tables show the values of pottery product in 1913 and a comparison of the production and values for the years 1912 and 1913:

Value of pottery products in 1913.

Kind	Value	Percentage of total Alabama Pottery's Products	Percentage of total U. S. Value
Red Earthenware	$11,164	55.40	1.12
Stoneware and Rockingham ware	8,994	44.60	0.24
Total	20,158	100.00	.05

Comparison of pottery products in 1912 and 1913.

Kind	1912	1913	Increase or Decrease	Percentage
Red Earthenware	$10,990	$11,164	+$ 174	1.58
Stoneware and Rockingham ware	11,223	8,994	— 2,229	19.87
Total	22,213	20,158	— 2,055	9.25

COAL.

E. W. Parker.

Introductory.

THE great Appalachian coal region which furnishes over two-thirds of the coal production of the United States and which extends from Ohio and Pennsylvania on the north in a gradually narrowing belt through eastern Kentucky and Tennessee has its southern terminus in a considerably broadened area that occupies a large part of the northern half of Alabama. The coal-bearing formations of Alabama underlie about 8,400 square miles and are divided into four distinct basins, the Coosa, the Cahaba, and the Warrior, named from the rivers which drain them, and the Plateau, which includes Blount, Lookout, and Sand or Raccoon Mountains. By far the most important basin in area and in production in the Warrior, which includes all of Walker County, most of Jefferson, Tuscaloosa, and Fayette counties, and smaller parts of Blount, Cullman, Winston, and Marion counties. The area known to contain coal is approximately 4,000 square miles, or one-half the total coal area of the State, and contributes about 80 per cent of the total production.

There are several distinct coal groups in the basin, the most important of which are the Brookwood, the Pratt, and the Mary Lee, designated by the names of their principal beds. The Mary Lee group includes the Blue Creek, the Jagger, and the Newcastle beds, most of which are mined in places. The Brookwood, the Pratt, and the Mary Lee produce most of the coking coal mined in the State, and more than half of all of the coal mined in the district.

The Cahaba Basin, second in importance, is a long narrow syncline, 68 miles long and about 6 miles wide, southeast of the Warrior, and occupies parts of St. Clair, Jefferson, Shelby, and Bibb counties. There are many workable beds, and the total quantity of coal in the basin is large. The production is something over 10 per cent of the total for the State.

The Coosa Basin is a deep syncline east of the Cahaba and parallel with it, extending across Shelby and St. Clair counties. It is also long and narrow, 60 miles long by 6 miles wide. It has not been thoroughly explored, but in different parts of the area from two to twelve beds, 3 or more feet in thickness, have been reported.

The Plateau field embraces parts of Blount, Etowah, DeKalb, Cherokee, Marshall, and Jackson counties, and although it has an area underlain by coal four times that of the Cahaba and the Coosa combined, the resources in Alabama are comparatively small. There are four to six beds locally workable.

So far as known, the earliest record of the existence of coal in Alabama was made in 1834. The first statement of production in the State is contained in the United States census report for 1840, in which year the production is given as 946 tons. The census report for 1850 does not mention any coal production for the State, and the next authentic record is contained in the census statistics of 1860, when Alabama is credited with an output of 10,200 short tons. The mines of Alabama were probably worked to a considerable extent during the Civil War, but there are no records of the actual production until 1870, for which year the United States census reports a production of 11,000 tons. Ten years later the production had increased to 323,972 short tons, but the development of the present great industry really began in 1881 and 1882, when attention was directed to the large iron deposits near the city of Birmingham and thus the great "boom" of that city and vicinity was inaugurated. By 1885 the coal production of the State had increased to nearly 2,500,000 tons. Then followed a period of relapse and liquidation, which lasted two years, after which business settled down to a conservative and rational basis and has since developed steadily. In 1902 the coal production of the State reached a total of more than 10,000,000 tons, and reached the maximum of 17,678,522 tons in 1913.

Production.

Total production in 1913, 17,678,522 short tons; spot value, $23,083,724.

The increase in coal production in Alabama in 1913 as compared with 1912 was 1,577,922 short tons, or 9.8 per cent, in quantity and $2,254,472, or 10.8 per cent, in value. The average value per ton advanced from $1.29 to $1.31. The increased production in 1913 was due to several causes. During a part of 1912 some of the larger companies were in the hands of receivers and this condition cut down the possible output for that year. The production was further restricted by the burning of the tipple at one of the large mines. The tipple was not rebuilt until the early part of 1913. Several new mines were opened in 1913 and these have been furnishing a gradually increasing output. Some of the older mines have added improvements and extended their workings to provide for an increased tonnage. Labor conditions were much better in 1913 than in either 1912 or 1911, for, although in some districts there was a scarcity rather than a surplus, other districts reported a better labor supply, miners having been recruited from other lines of employment. Car shortage was less acute than in recent years prior to 1913, as some of the large coal-carrying roads have added materially to their facilities for handling the output. The increased tonnage went principally to points outside the State, as the demand for manufacturing, transportation, and domestic consumption within the State was not above normal. The most notable feature in the trade was the increased bunker requirements on the Gulf coast and larger shipments of coke to western points. The relations between operators and mine workers were generally harmonious and increased wages were put in force in February. Earnings by miners and mine laborers in 1913 are said to have been higher than ever before in the history of coal mining in Alabama. Improved sanitary and living conditions put into effect by many companies added to the general betterment.

The average tonnage per man for 1913 showed an increase over 1912 from 712 to 720, but there was a slight falling off in the average output per man per day from 2.91 to 2.82. The former was due to the larger number of days worked—255 in 1913 against 245 in 1912, and the latter partly to the amount of development work in progress during 1913 and partly to the larger number of new recruits. The number of men employed in 1913 was 24,552, against 22,613 in 1912.

The production by the use of machines increased from 3,742,549 short tons in 1912 to 4,124,301 tons in 1913, the per centage to the total output being about the same in both years, 23.2 per cent in 1912 and 23.3 per cent in 1913. The number of machines increased from 353 to 377. Of the latter 249 were punchers, 42 chain breast, 20 long wall, and 66 short wall. It is unfortunate to be obliged to record a marked increase in the quantity and percentage of coal shot off the solid. In 1912 the quantity of powder-mined coal reported was 5,658,457, or 35.1 per cent of the total; in 1913 it was 7,052,234 tons, or 39.9 per cent. The hand-mined coal decreased from 6,658,732 tons, or 41.4 per cent, in 1912, to 6,315,787 tons, or 35.7 per cent, in 1913.

The statistics of fatal accidents compiled by the Bureau of Mines shows that there were 124 men killed in the coal-mining operations of Alabama in 1913, all but 1 underground. More than half of the deaths, 68 in all, were due to falls of roof and coal, 27 to gas and dust explosions (including suffocations by mine gases), and 19 to mine cars and locomotives. In 1912 there were 121 fatal accidents in Alabama coal mines. The death rate per thousand in 1913 was 5 against 5.4 in 1912, and the number of tons mined for each life lost was 142,569 against 133,063.

The total time lost by strikes in 1913 was 27,041 days, 1,048 men being idle for an average of 26 days.

Nearly one-half of the coal mined in Alabama in 1913 was washed before being marketed or used in the manufacture of coke. The quantity washed was 8,149,082 tons, yielding 7,210,588 tons of cleaned coal and 938,494 tons of refuse. The difference of 1.3 per cent between the production as reported to the Geological Survey and to the State mine inspector is probably due to the inclusion in the reports to the latter of some of the refuse and its omission in the reports to the Survey. The quantity of refuse actually reported to the Survey as removed at the mines and deducted from the gross tonnage was more than twice the difference between the Federal and State figures.

The statistics of production of coal in Alabama in 1912 and 1913, with the distribution of the product for consumption, are shown in the following table:

Coal production of Alabama in 1912 and 1913, by counties, in short tons.

1912.

County	Loaded at mines for shipment	Sold to local trade and used by employees	Used at mines for steam and heat	Made into coke	Total quantity	Total value	Average price per ton	Average number of days active	Average number of employees
Bibb	1,662,198	9,823	109,814	....	1,781,335	$2,621,682	$1.47	272	2,948
Blount	143,603	1,139	1,600	....	146,342	181,036	1.24	211	282
Etowah	166,366	3,067	1,875	....	171,308	249,749	1.46	265	260
Jefferson	6,168,715	81,368	339,211	1,585,555	8,174,849	10,433,728	1.28	251	10,922
St. Clair	722,276	2,456	25,021	....	749,753	959,219	1.28	291	725
Shelby	463,788	3,501	29,660	....	496,949	872,501	1.76	250	878
Tuscaloosa	631,114	12,038	48,863	188,952	880,967	1,091,882	1.24	239	1,220
Walker	3,271,284	32,030	102,681	141,967	3,547,962	4,158,094	1.17	211	5,079
Winston	18,550	105	75	....	18,730	27,793	1.48	220	57
Other counties* and small mines	124,627	2,059	5,719	....	132,405	233,568	1.76	229	242
Total	13,372,521	147,586	664,019	1,916,474	16,100,600	20,829,252	1.29	245	22,613

1913.

County	Loaded at mines for shipment	Sold to local trade and used by employees	Used at mines for steam and heat	Made into coke	Total quantity	Total value	Average price per ton	Average number of days active	Average number of employees
Bibb	1,802,243	9,214	99,569	....	1,911,026	$2,979,240	$1.56	274	3,158
Blount	174,580	2,758	1,620	....	178,958	236,448	1.32	203	354
Etowah	135,815	725	1,252	....	137,792	171,600	1.25	256	209
Jefferson	7,149,844	83,353	412,891	1,382,746	9,028,834	11,790,737	1.31	266	11,643
St. Clair	861,579	2,909	25,891	....	890,379	1,150,457	1.29	277	798
Shelby	457,313	4,469	35,787	....	497,569	862,783	1.73	257	850
Tuscaloosa	699,690	13,891	68,836	134,888	917,305	1,172,227	1.28	271	1,183
Walker	3,671,708	42,809	101,760	150,986	3,967,263	4,481,373	1.13	223	6,031
Winston	24,841	60	50	....	24,951	36,721	1.47	228	67
Other counties*	116,423	2,162	5,030	....	123,615	200,059	1.62	233	259
Small mines	....	830	....	....	830	2,076	2.50	....	....
Total	15,094,036	163,180	752,686	1,668,620	17,678,522	23,083,724	1.31	255	24,552

*Cullman, Jackson, and Marion.

In the following table is presented a statement of the production of coal in Alabama, by counties, during the last five years, with increase and decrease in 1913 as compared with 1912:

Coal production of Alabama, 1909-1913, by counties, in short tons.

County	1909	1910	1911	1912	1913	Increase (+ or decrease (—), 1913
Bibb	1,338,243	1,580,564	1,633,197	1,781,335	1,911,026	+ 129,691
Blount **Cullman**	186,261	*235,456	*210,070	*276,429	*300,092	+ 23,663
Etowah	46,194	172,465	255,860	171,308	137,792	— 33,516
Jefferson	7,176,922	8,298,702	7,776,390	8,174,849	9,028,834	+ 853,985
St. Clair	354,005	428,409	529,211	749,753	890,379	+ 140,626
Shelby	524,925	488,141	463,089	496,949	497,569	+ 620
Tuscaloosa	1,006,989	1,081,219	1,031,658	880,967	917,305	+ 36,338
Walker	2,973,776	3,788,479	3,103,595	3,547,962	3,967,263	+ 419,301
Winston	32,278	16,442	16,424	18,730	24,951	+ 6,221
Other counties and small mines	63,857	21,585	1,927	2,318	3,311	+ 993
Total	13,703,450	16,111,462	15,021,421	16,100,600	17,678,522	+ 1,577,922
Total value	$16,306,236	$20,236,853	$19,079,949	$20,829,252	$23,083,724	+$2,254,472

***Includes production of Marion County.**

The statistics of production in Alabama from 1840 to the close of 1913 are shown in the following table:

Production of coal in Alabama from 1840 to 1913, in short tons.

Year	Quantity	Year	Quantity	Year	Quantity	Year	Quantity
1840	946	1859	9,000	1878	224,000	1897	5,893,770
1841	1,000	1860	10,200	1879	280,000	1898	6,535,288
1842	1,000	1861	10,000	1880	323,972	1899	7,593,416
1843	1,200	1862	12,500	1881	420,000	1900	8,394,275
1844	1,200	1863	15,000	1882	896,000	1901	9,099,052
1845	1,500	1864	15,000	1883	1,568,000	1902	10,354,570
1846	1,500	1865	12,000	1884	2,240,000	1903	11,654,324
1847	2,000	1866	12,000	1885	2,492,000	1904	11,262,046
1848	2,000	1867	10,000	1886	1,800,000	1905	11,866,069
1849	2,500	1868	10,000	1887	1,950,000	1906	13,107,963
1850	2,500	1869	10,000	1888	2,900,000	1907	14,250,454
1851	3,000	1870	11,000	1889	3,572,983	1908	11,604,593
1852	3,000	1871	15,000	1890	4,090,409	1909	13,703,450
1853	4,000	1872	16,800	1891	4,759,781	1910	16,111,462
1854	4,500	1873	44,800	1892	5,529,312	1911	15,021,421
1855	6,000	1874	50,400	1893	5,136,935	1912	16,100,600
1856	6,800	1875	67,200	1894	4,397,178	1913	17,678,522
1857	8,000	1876	112,000	1895	5,693,775		
1858	8,500	1877	196,000	1896	5,748,697	Total	254,954,358

The following tables give other details concerning the coal production of Alabama, including areas of the coal fields of Alabama and of the United States, with estimates of original and present supply, etc.; rank of first five coal-producing States; production by classes of mines; labor statistics; strikes and suspensions; machines used and methods of mining, etc.:

Area of coal fields of Alabama and of the United States, estimates of original and present supply, and the production to the close of 1913.

	Area	Estimated original supply	Production in 1913	Total production to close of 1913	Total exhaustion to close of 1913	Estimated available supply
	Sq. Mi.	Short Tons	Sh. Tons	Short Tons	Short Tons	Short Tons
Alabama	8,455	67,583,000,000	17,678,522	254,954,358	382,400,000	67,200,600,000
U. S.	450,839	3,553,383,400,000	570,048,125	9,844,247,843	15,877,071.700	3,538,506,328,300

Rank of first ten coal-producing States in 1912 and 1913, with quantity and value of products and percentage of each.

1912.

Production				Value			
Rank	State or Territory	Quantity (short tons)	Percentage of total product'n	Rank	State or Territory	Value	Percentage of total value
1	Pennsylvania:			1	Pennsylvania:		
	Anthracite	84,361,598	15.8		Anthracite	$177,622,626	25.6
	Bituminous	161,865,488	30.3		Bituminous	169,370,497	24.4
2	West Virginia	66,786,687	12.5	2	Illinois	70,294,338	10.1
3	Illinois	59,885,226	11.2	3	West Virginia	62,792,234	9.0
4	Ohio	34,528,727	6.4	4	Ohio	37,083,363	5.3
5	Kentucky	16,490,521	3.1	5	Alabama	20,829,252	3.0
6	Alabama	16,100,600	3.0	6	Indiana	17,480,546	2.5
7	Indiana	15,285,718	2.8	7	Kentucky	16,854,207	2.4
8	Colorado	10,977,824	2.0	8	Colorado	16,345,336	2.4
9	Virginia	7,846,638	1.5	9	Iowa	13,152,088	1.9
10	Wyoming	7,368,124	1.4	10	Wyoming	11,648,088	1.7

1913.

Production				Value			
Rank	State or Territory	Quantity (short tons)	Percentage of total product'n	Rank	State or Territory	Value	Percentage of total value
1	Pennsylvania:			1	Pennsylvania:		
	Anthracite	91,524,922	16.1		Anthracite	$195,181,127	25.7
	Bituminous	173,781,217	30.5		Bituminous	193,039,806	25.4
2	West Virginia	71,308,982	12.5	2	West Virginia	71,872,165	9.5
3	Illinois	61,618,744	10.8	3	Illinois	70,313,605	9.2
4	Ohio	36,200,527	6.3	4	Ohio	39,948,058	5.3
5	Kentucky	19,616,600	3.4	5	Alabama	23,083,724	3.0
6	Alabama	17,678,522	3.1	6	Kentucky	20,516,749	2.7
7	Indiana	17,165,671	3.0	7	Indiana	19,001,881	2.5
8	Colorado	9,232,510	1.6	8	Colorado	14,035,090	1.8
9	Virginia	8,828,068	1.5	9	Iowa	13,496,710	1.8
10	Iowa	7,525,936	1.3	10	Kansas	12,036,292	1.6

Production of coal in Alabama in 1912 and 1913, according to classes of mines, in short tons.

1912.

	Mines		Production		
	Number	Percentage	Total	Average	per Mine
First Class: (Mines producing over 200,000 tons)	13	6.0	3,734,754	287,289	23.2
Second Class: (Mines producing from 100,000 to 200,000 tons)	50	23.0	7,364,764	147,295	45.7
Third Class: (Mines producing from 50,000 to 100,000 tons)	41	18.9	2,967,102	72,368	18.4
Fourth Class: (Mines prdoucing from 10,000 to 50,000 tons)	75	34.6	1,843,623	24,582	11.5
Fifth Class: (Mines producing less than 10,000 tons)	38	17.5	190,357	5,009	1.2
Total	217	....	16,100,600	74,196	....

1913.

First Class: (Mines producing over 200,000 tons)	19	8.5	6,112,051	321,687	34.6
Second Class: (Mines producing from 100,000 to 200,000 tons)	42	18.7	5,862,478	139,583	33.2
Third Class: (Mines producing from 50,000 to 100,000 tons)	44	19.6	3,121,545	70,944	17.6
Fourth Class: (Mines producing from 10,000 to 50,000 tons)	94	42.0	2,448,122	26,044	13.8
Fifth Class: (Mines producing less than 10,000 tons)	25	11.2	133,496	5,340	0.8
Total	224	....	17,677,692	78,918	....

LABOR STATISTICS.

Statistics of labor employed in coal mines of Alabama 1908-1913.

Year	Number of days active	Average Number Employed
1908	222	19,197
1910	249	22,210
1911	227	22,707
1912	245	22,613
1913	255	24,552

Average production per man compared with hours worked per day, and average number of days worked 1910-1912.

Year	8 hours		9 hours		10 hours		All others	Total	Days Worked	Average Tonnage	
	Mines	Men	Mines	Men	Mines	Men	Men	Men		Per Year	Per Day
1910	13	766	36	2,683	134	17,306	1,525	22,280	249	725	2.91
1911	15	550	50	5,345	102	12,628	4,184	22,707	227	662	2.92
1912	11	338	46	4,145	107	13,938	4,192	22,613	245	712	2.91
1913	13	420	36	2,496	135	18,185	3,451	24,552	255	720	2.82

Statistics of labor strikes in the coal mines of Alabama in 1912 and 1913.

1912			1913		
Number of men on strike	Total days lost	Average number of days lost per man	Number of men on strike	Total days lost	Average number of days lost per man
384	12,328	32	1,048	27,041	26

MACHINES USED AND METHODS OF MINING.

Number and kind of machines in use in Alabama in 1912 and 1913.

Year	Pick	Chain Breast	Long Wall	Short Wall	Total
1912	222	60	12	59	353
1913	249	42	20	66	377

Bituminous coal mined by machines in Alabama in 1912 and 1913.

Year	Number of machines in use	Number of tons mined by machines	Total tonnage of Alabama	Percentage of total product mined by machines
1912	353	3,742,549	16,100,600	23.2
1913	377	4,124,301	17,678,522	23.3

Quantity and percentage of coal mined by different methods in Alabama in 1912 and 1913, short tons.

Year	Mined by hand	Percentage	Shot off the solid	Percentage	Mined by machines	Percentage	Not reported	Percentage	Total production
1912	6,658,732	41.4	5,658,457	35.1	3,742,549	23.2	40,862	0.3	16,100,600
1913	6,315,787	35.7	7,052,234	39.9	4,124,301	23.3	186,200	1.1	17,678,522

COAL WASHING OPERATIONS.

Coal washed at the mines in Alabama in 1912 and 1913, with quantity of washed coal and of refuse obtained from it, short tons.

Year	Quantity of coal washed	Quantity of cleaned coal	Quantity of refuse
1912	7,187,211	6,325,946	861,265
1913	8,149,082	7,210,588	938,494

AVERAGE VALUE OF ALABAMA COAL.

Average value per short ton for coal at the mines in Alabama since 1908.

1908	1909	1910	1911	1912	1913	Advance in 1913
$1.26	$1.19	$1.26	$1.27	$1.29	$1.31	$0.02

COKE.

E. W. Parker.

THE production of coke in Alabama increased from 2,975,489 short tons, valued at $8,098,412, in 1912, to 3,323,664 tons, valued at $9,627,170, in 1913. The gain was 348,175 tons, or 11.7 per cent, in quantity, and $1,528,758, or 18.9 per cent, in value. All of the increased production, and more, was in the output of retort oven or by-product coke. There are in Alabama four retort oven establishments with a total of 700 ovens, and in 1913 these establishments produced 2,022,959 tons of coke, or a little more than 60 per cent of the total output, whereas 22 active beehive plants with an aggregate of 4,135 ovens in blast produced 1,300,705 tons, or a little less than 40 per cent of the total. The average production per oven in the by-product plants was 2,890 tons, and the average production for each beehive oven was 315 tons.

The increase in the production of by-product coke in 1913 over 1912 was 673,162 tons, or nearly double the total increase. The output of beehive coke decreased 324,987 tons. The value of the by-product coke showed an increase of $1,751,538, or $222,780 more than the total increase, the difference representing the decrease in the value of beehive coke. Moreover, the average yield of coal in coke from the retort ovens was 71.4 per cent, whereas the average yield in the beehive ovens was 54.5 per cent. There is not the marked difference in the values of retort and beehive cokes (and in favor of the former) in Alabama as is shown in some States, for in Alabama the retort ovens, like the beehive, are located near the mines, and the two in that respect are somewhat on a parity, whereas in most of the States where retort coke is made the ovens are at considerable distances from the mines, and the transportation charges assessed against the coal are added to the value of the coke. In fact the Alabama, beehive coke had a higher value per ton in 1913 than the retort coke, the averages per ton being $3.38 for beehive coke and $2.58 for retort coke. The explanation of this seeming inconsistency lies in the fact that all of the retort coke is used by the producers in their own furnaces, and the coke is charged to the furnaces at little more than cost, whereas the greater part of the beehive product is commercial coke, some of it for foundry use, and profits are included in the value.

That the beehive oven has had its day in Alabama and is on the decline is evinced by the facts that no new ovens of that type have been built in the last four years and that 20 establishments, with a total of 3,447 ovens, out of a total of 42 establishments, with 9,548 ovens, were idle in 1913, not counting the ovens out of blast at plants that produced some coke in 1913. There were fewer beehive ovens in existence in Alabama in 1913 than in 1908, five years before. The number of retort ovens increased from 620 in 1912 to 700 in 1913, 80 of the 100 ovens of that type reported as in course of construction at the close of 1912 having been completed and put in blast. The 700 completed ovens include 280 Semet-Solvay ovens (240 at Ensley and 40 at Tuscaloosa and 420 Koppers ovens (280 at Fairfield, formerly known as Corey, and 140 at Woodward). The only new ovens in course of construction at the close of 1913 were 20 Semet-Solvay ovens which were being added to the Tuscaloosa plant.

RANK OF COKE-PRODUCING STATES.

The record of coke production in 1913 effected few changes in the relative importance of the State in connection with that industry. Virginia superseded Colorado as sixth in rank, but with that exception the first 12 States held the same position in 1913 as in 1912. Pennsylvania, of course, stands preeminently first, with Alabama second, Indiana third, and West Virginia fourth, but if all the coke made from West Virginia coal were produced in that State it would be well fixed in second place, as by far the larger part of the coke manufactured in Ohio, Indiana, and Illinois is from West Virginia coal. As, however, the production of coke in retort ovens at or near the points of consumption is likely to continue to increase in greater proportion and the beehive ovens to disappear gradually from the mining regions, it is not probable that West Virginia will again assume its former importance as a coke-producing State.

The quantity of coke made in West Virginia in 1913 was less than one-half of that made from West Virginia coal in ovens outside the State.

The positions held by the coke-producing States are shown in the following table:

Rank of the States in production of coke, 1909-1913.

State	1909	1910	1911	1912	1913	State	1909	1910	1911	1912	1913
Pennsylvania	1	1	1	1	1	Tennessee	13	13	14	14	13
Alabama	3	3	2	2	2	Ohio	15	14	15	13	14
Indiana	22	17	6	3	3	Utah	16	16	17	15	15
West Virginia	2	2	3	4	4	Kentucky	19	20	19	18	16
Illinois	5	4	4	5	5	New Jersey	14	15	16	17	17
Virginia	4	5	7	7	6	Maryland	12	12	13	16	18
Colorado	6	6	5	6	7	Minnesota	17	18	18	19	19
New York	7	7	8	8	8	Washington	20	19	20	20	20
Wisconsin	8	8	9	9	9	Georgia	18	21	21	21	21
Massachusetts	9	9	10	10	10	Kansas	......	24	22	22	......
Michigan	11	11	12	11	11	Montana	21	22	......	......	......
New Mexico	10	10	11	12	12	Oklahoma	......	23	......	......	......

The production of coke in Alabama in 1880, 1890, 1900, and annually from 1909 to 1913, is shown in the following table:

Statistics of the manufacture of coke in Alabama, 1880-1913.

Year	Establishments	Ovens		Coal used (short tons)	Yield of coal in coke (per cent)	Coke produced (short tons)	Total value of coke at ovens	Value of coke at ovens per ton
		Built	Building					
1880	4	316	100	106,283	57.0	60,781	$183,063	$3.01
1890	20	4,805	371	1,809,964	59.0	1,072,942	2,589,447	2.41
1900	30	6,529	690	3,582,547	58.9	2,110,837	5,629,423	2.67
1909	43	10,061	0	5,080,764	60.7	3,085,824	8,068,267	2.61
1910	43	10,132	340	5,272,322	61.6	3,249,027	9,165,821	2.82
1911	44	10,121	280	4,411,298	62.6	2,761,521	7,593,594	2.75
1912	46	10,208	100	4,585,498	64.9	2,975,489	8,098,412	2.72
1913	46	*10,284	†20	5,218,323	63.6	3,323,664	9,267,170	2.90

*Includes 280 Semet-Solvay and 420 Koppers ovens. †Semet-Solvay ovens.

Comparison of the production and value of coke in Alabama in 1912 and 1913.

	Number of ovens	Coal charged (short tons)	Coke produced (short tons)	Total value of coke at ovens	Percentage of total U. S. value
1912	10,208	4,585,498	2,975,489	$8,098,412	7.24
1913	10,284	5,218,323	3,323,664	9,627,170	7.46
Increase	76	632,825	348,175	1,528,758	....
Percentage	0.74	13.8	11.7	18.9	....

More than 80 per cent of the coal used in the manufacture of coke in Alabama is washed before being charged into the ovens. In 1913, out of a total of 5,218,323 tons of coal made into coke, 4,349,664 tons were washed. Of the washed coal used, 3,665,441 tons were slack and 684,223 tons were mine run. The unwashed mine-run coal used was 868,659 tons. No unwashed slack was used in 1913.

The character of the coal used in the manufacture of coke in Alabama in 1890, 1900, and for the last five years, is shown in the following table:

Character of coal used in the manufacture of coke in Alabama, 1890-1913, in short tons.

Year	Run of mine		Slack		Total
	Unwashed	Washed	Unwashed	Washed	
1890	1,480,669	0	206,106	123,189	1,809,964
1900	1,729,882	152,077	165,418	1,535,170	3,582,547
1909	713,992	2,153,801	0	2,212,971	5,080,764
1910	771,931	1,308,085	0	3,192,806	5,272,822
1911	693,135	1,295,109	2,937	2,420,117	4,411,298
1912	747,305	896,421	18,793	2,922,979	4,585,498
1913	868,659	684,223	0	3,665,441	5,218,323

Quantity and value of coal used in the manufacture of coke in Alabama in 1912 and 1913, and quantity and value of same per ton of coke.

Year	Coal used (short tons)	Total value of coal	Value of coal per ton	Quantity of coal per ton of coke (short tons)	Value of coal to a ton of coke
1912	4,585,498	$6,177,876	$1.35	1,541	$2,080
1913	5,218,323	7,609,963	1.46	1,570	2,292

Character of coal used in the manufacture of coke in Alabama in 1912 and 1913, in short tons.

Year	Run of mine		Slack		Total			
	Unwashed	Washed	Unwashed	Washed	Unwashed	Percentage	Washed	Percentage
1912	747,305	896,421	18,793	2,922,979	766,098	16.7	3,819,400	83.3
1913	868,659	684,223	0	3,665,441	868,659	16.6	4,349,664	83.4

Statistics of the production of coke in beehive and retort ovens in Alabama, 1912 and 1913.

Year	Beehive coke		By-product coke		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1912	1,625,692	$4,623,996	1,349,797	$3,474,416	2,975,489	$8,098,412
1913	1,300,705	4,401,216	2,022,959	5,225,954	3,323,664	9,627,170

Record of by-product ovens in Alabama 1909-1913.

Year	Built	Building
December 31, 1909	280	0
December 31, 1910	280	340
December 31, 1911	340	280
December 31, 1912	620	100
December 31, 1913	700	20

Complete list of retort coke-oven plants of Alabama, Jan. 1, 1914.

Town	System	Name of company owning plant	Number of installments	Date put in operation	Number of ovens	Uses of coke	Uses of surplus gas
Ensley (near Birmingham)	Semet-Solvay	Tennessee Coal, Iron & R. R. Co.	First	Oct., 1898	120	Blast furnace	Fuel
			Second	Mar., 1902	120	Blast furnace.	Fuel
Tuscaloosa	Semet-Solvay	Central Iron & Coal Co.	First	Feb., 1906	40	Blast furnace	Fuel
Woodward	Koppers	Woodward Iron Co.	First	1911	60	Blast furnace	Fuel and power
Woodward	Koppers	Woodward Iron Co.	Second	1913	80	Blast furnace	Fuel and power
Fairfield	Koppers	Tennessee Coal, Iron & R. R. Co.	First	1912	280	Blast furnace	Fuel and power

GOLD AND SILVER.

H. D. McCaskey.

THE mine production of gold in Alabama in 1913 was 536.67 fine ounces, valued at $11,094, and of silver 117 fine ounces, valued at $71, against 809.0 fine ounces of gold valued at $16,724, and 168 fine ounces of silver valued at $103, in 1912. The gold output was all from gold quartz mines and the silver production was entirely from refining the gold bullion produced. No copper, lead or zinc output was reported from Alabama in either 1912 or 1913.

The following table shows the mine production of gold and silver in Alabama since 1905, when the United States Geological Survey first collected detailed figures from the mines of the Eastern States. The decrease of production shows results from comparison with the corresponding Survey mine figures for 1912.

Production of gold and silver in Alabama from 1905 to 1913, inclusive.

	Ore Sold or Treated (short tons)	Gold		Silver		Total value
		Quantity oz.	Value	Quantity oz.	Value	
1905	16,425	2,009.0	$41,580	336	$208	$41,788
1906	8,565	1,187.0	24,921	124	83	25,004
1907	18,400	1,256.9	25,982	439	290	26,272
1908	11,174	1,993.4	41,208	282	149	41,357
1909	9,886	1,414.4	29,239	212	110	29,349
1910	9,763	1,662.2	33,533	268	145	33,678
1911	6,860	915.0	18,916	171	91	19,007
1912	5,698	809.02	16,724	168	103	16,827
1913	....	536.67	11,094	117	71	11,165
Decrease in 1913	....	272.35	5.630	51	32	5.662
Percentage	....	33.66	33.66	30.36	31.07	33.65

GRAPHITE.

BY EDSON S. BASTIN.

GRAPHITE is widely distributed among the metamorphic rocks of Alabama,[1] in which it occurs in two forms: (1) In the feebly crystalline schists which have been called the Talladega slates,[2] and which in part at least are Paleozoic sediments of as late age as the "Coal Measures," graphite is often found as a black graphitic clay free from grit. In this condition the graphite is difficult to separate from the other matter with which it is mixed, and the material has not yet been utilized commercially to any great extent. Examples of this mode of occurrence may be seen near Millerville, in Clay County, and about Blue Hill, in Tallapoosa County. (2) In the mica schists and other highly crystalline rocks graphite is found in the form of thin crystalline flakes, which may be separated from the associated minerals. Graphitic schists of this type are now being worked at three localities and have in the past been worked at several others.

Three graphite companies were active in Alabama during 1913. One of these, the Alabama Graphite Co., with mine and mill 6 miles west of Ashland, Clay County, reported a notable increase in production as compared with 1912. The other, the Quenelda Graphite Co. (formerly the Allen Graphite Co.), at Quenelda, Clay County, has completed a new mill to replace the one destroyed by fire in 1911. This mill was put in operation November 1, 1913, and an important quantity of flake graphite was marketed during the year. .The mine and mill 4½ miles west of Ashland, formerly operated by the Ashland Graphite Co., have not been in operation since 1911, and it is reported that the company has dissolved. The Flaketown Graphite Co., near Mountain Creek, in Chilton County, reported an important production.

The properties of the Quenelda Graphite Co. and that formerly operated by the Ashland Graphite Co. and a few other

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[1] Smith, E. A., Min. Industry, vol. 16, p. 568, 1907.

[2] McCalley, H., Alabama Geol. Survey Rept. valley regions, pt. 2, pp. 36-38, 1897.

Alabama graphite properties were visited by the writer in 1911. The original reports upon them being exhausted, his observations are reprinted below. The property of the Alabama Graphite Co. was not developed at that time and has not since been visited.

CLAY COUNTY.

Ashland, the shipping point of the Clay County graphite properties, is the terminus of a short branch of the Atlanta, Birmingham & Atlantic Railroad. This branch is 7 miles long and joins the main line at Pyriton. The freight rate on refined graphite from Ashland to New York City is about $7 a long ton.

QUENELDA GRAPHITE CO. (FORMERLY THE ALLEN GRAPHITE CO.)

The quarry and mill of this company are located a little over 8 miles west of Ashland, at a settlement shown on the United States Geological Survey's map of the Ashland quadrangle under the name "Graphite." The mine is about half a mile from the mill, with which it is connected by a tramway. The concentrate is hauled over a fairly good road to Ashland for shipment. The mining is entirely from open pits, and because of the decomposed character of the rock can be accomplished largely with the aid of pick, shovel, and crow-bar, without much drilling and blasting.

The main pit is about 450 feet in length, 100 feet in average width, and about 60 feet in maximum depth. A small pit just east of the main pit and on the same graphitic band is about 100 feet long, 90 feet wide, and 25 feet deep. A third pit has been opened on the same band of graphitic schist about 1,000 feet east of the main pit on the west face of another hill. This is about 90 feet wide, about 200 feet long, and about 40 feet deep. The strike of the schist at the north end of the main pit is N. 80° E., with a dip of 75° S. This is fairly typical for the deposit as a whole.

The rock mined is highly schistose and is composed largely of quartz and graphite. A white, fibrous mineral, probably sillimanite, is also abundant. Feldspar and mica are rare. Few of the thin graphite flakes so far seen by the writer exceed 2 millimeters across and most of them are under 1½ millimeters. They are arranged subparallel to one another, and to this arrangement and a similar orientation of the sillimanite (?) prisms is largely due the schistosity of the rock. At the west end of the main pit a dike of coarse granite, 1 to 1½ feet wide, parallels the foliation of the schist, and in the easternmost pit the graphitic schist has also been intruded by an irregular body of coarse granite pegmatite carrying muscovite crystals up to 3 inches across. The graphitic beds here are also disturbed by faulting. The contact metamorphic effects of these small intrusions on the graphitic schist appear to be slight.

The mill which was in operation at the time of the writer's visit has since been destroyed by fire and replaced by a new one, but as the old mill was studied in some detail a description of the process may still be of value.

The milling process in the old mill was divided into three principal stages—(1) crushing and drying; (2) preliminary wet concentration; and (3) final dry concentration.

The most important step in the milling process was the preliminary concentration by water flotation. In these concentrators the dry crushed rock was spread in a thin stream upon the surface of slowly flowing water. The graphite being flaky was supported by the surface tension of the water and floated off, while the granular gangue, mainly quartz, sank and was sent to the dump. The process is cheap where water is plentiful. The tailings seen on the dump carried surprisingly little graphite; that which was present was usually attached to other minerals. Much fine grit, of course, floated off with the graphite but was removed in the final dry concentration.

The crude rock was said by the operators to average about 5 per cent graphite. For two successive years (September, 1908, to September, 1910) the finished product formed, respectively, 2.95 and 2.7 per cent by weight of the crude rock treated. Four principal grades were produced, whose relative proportions were about as follows:

Grades of flake graphite produced by Allen Graphite Co., Clay County, Alabama.

		Per cent.
Grade C.	Crucible flake	36
Grade 1.	Lubricating flake (coarse)	11
Grade 2.	Lubricating flake (fine)	18
Grade D.	Dust for foundry facings, etc.	35
		100

The highest grade averaged over 90 per cent graphite; the dust average about 50 per cent graphite. The average prices f. o. b. New York in 1911 were: Grade C, 6½ cents per pound; grade 1, 5½ cents per pound; grade 2, 4½ cents per pound; and grade D, 1 cent per pound.

ASHLAND GRAPHITE CO.

The quarry and mill of the Ashland Graphite Co., which has not been a producer since 1911, are located about 4½ miles west of Ashland. The company was the successor to the Enitachopco Graphite Co. The product of the plant was hauled by team to Ashland. The workings at this property consist of two open pits located in the same belt of graphite schist. The two pits are on neighboring knolls, and the mill is in the small valley between them. The largest or eastern pit is about 400 feet long, 30 to 50 feet wide, and 50 feet deep. It follows along the strike of a band of graphitic schist which averages about 30 feet in width, though broadening locally to about 50 feet. The strike is about N. 55° E. and the average dip is about 45° E. The second pit, located west of the mill, is about 150 feet long, 20 feet wide, and about 20 feet deep. The trend of the schists is similar to that at the larger pit.

The graphitic rock at this quarry is similar in general to that at Quenelda quarry. The schist is too much decomposed for the complete identification of all the minerals, but quartz is the principal component. As a rule mica is rare, but the brown mica biotite is common in a few places. The graphite forms thin flakes, mostly under 1 millimeter in diameter, although some reach 2 millimeters. No igneous rocks were seen in association with the graphitic schist at this property. The rock being more or less decomposed, can be excavated with pick and crowbar with occasional blasting. It is loaded into tramcars and hauled to the mill.

COOSA COUNTY.

A graphite prospect is located about 2 miles northwest of Goodwater, a station on the Central of Georgia Railway. At this locality a large number of small prospect pits are scattered over an area of several acres, and nearly all show graphitic quartz schist. The prospects are on a steep southwest hillside overlooking the iron bridge where the wagon road from Goodwater to Pine Grove crosses Hatchet Creek. The rock is gray when fresh and highly schistose and strikes nearly east and west, with a dip of about 45° S. It is almost identical in character with the graphitic schist worked in Clay County and consists largely of quartz and graphite, the latter in flakes mostly under 1 millimeter in diameter. Very little mica is present. An analysis of a composite sample of graphitic schist collected from a large number of pits on this property showed 2 per cent of graphite, but in certain portions the percentage will undoubtedly be greater. The deposit is unquestionably a large one and its situation on a steep hillside would afford opportunity to work to a considerable depth by open-pit methods. The neighboring Hatchet Creek could furnish abundant water for wet concentration of the graphite.

A second deposit, probably of similar character, has been prospected between Mount Olive and Hollins. It was not visited by the writer, but is said to be of considerable size.

Production and vaule of crystalline graphite in 1912 and 1913.

	Quantity Pounds	Value	Percentage of total U. S. quantity	Percentage of total U. S. value
1912	534,100	$21,364	6.95	9.68
1913	2,020,910	87,336	29.73	29.73
Increase	1,486,810	65,972		
Percentage	278.38	308.80		

IRON ORE.

EUGENE A. SMITH.

IRON ores of Alabama in the order of their economic importance are (1) red ore or hematite; (2) the brown ore or limonite; (3) the gray ore. The black band and clay iron stone have been noticed as occurring in a number of places, but only the red ore and the brown ore have been mined on any large scale.

Practically all the ore mined in Alabama is smelted in the State, the shipments out of the State being about equal to those received from other states.

The tables given below will show the rank of Alabama among the States of the Union both in the production of iron ore and in pig iron.

RED ORE OR HEMATITE.

Practically all the ore of this quality mined in Alabama occurs in the Clinton or Red Mountain formation. The Red Mountain ridges occur on each side of the anticlinal valleys which separate the coal fields. In places the red ore ridges are lacking on one side, usually the western, of the valleys being cut out by faults, while on the other hand the ridge may be duplicated on one side of the valley by the same faults.

In most of the valley occurrences the moderate dips of the ore bed are on the eastern side and there are also practically all of the ore mines. Murphrees Valley makes an exception to this, the moderate dips and the iron mines being on the western side. The iron ore occurs mainly in the central part of the formation in seams or beds one to five in number, which vary in thickness from a few inches to thirty feet.

While the ore seams are very persistent along the outcrop which in Alabama must be as much as 50 miles, yet they vary greatly from place to place, being either too thin or too lean for profitable working in the greater part of this distance.

The most important development of the Clinton ore in this State and in the world is along the 15 or 16 miles stretch of the east Red Mountain between Birmingham and Bessemer, and there is a practically continuous series of mines and strippings for this entire distance. Much mining of this ore has also been done near Gate City, Village Springs, Attalla, Gadsden, Round Mountain, Gaylesville, Ft. Payne, Valley Head, etc.

The completion in October, 1912, of a diamond drill boring in Shades Valley, within a mile of the base of Shades Mountain, gives a definite answer to the speculations concerning the occurrence of red ore under Shades Valley. This boring shows that there is no falling off in the thickness and quality of the ore with distance from the outcrop, and that the depth of the ore below the surface at a distance of more than 2½ miles from the outcrop on Red Mountain is not too great for shaft mining.

The elevation of the surface at the drilling is 595 feet. The top of the ore was reached at a depth of 1,902 feet and a section of the seam in descending order is:

Ore (Self-fluxing)	9 ft. 6 in.
Shale	4 in.
Ore (Siliceous)	9 ft. 6 in.

An analysis of an average sample of the drill of the core of the upper bench, made by David Hancock, shows as follows:

	Per Cent.
Metallic iron	39.51
Silica	9.94
Alumina	3.34
Calcium Carbonate	24.20
Magnesium carbonate	.78
Metallic manganese	.20
Phosphorus	.32

The importance of this demonstration of a vast increase in the amount of red ore available immediately or in the near future, cannot well be overestimated.

In 1913 the Gulf States Steel Company acquired about 1,500 acres of land upon which the drill hole above mentioned was located. They commenced sinking double track slope to the ore, and the work is now about half completed (December, 1914). No serious difficulties have been encountered so far and it is probable that in about a year they will have reached the ore. In time this is likely to be the largest producing mine in the district.

Another drill hole was put down in Shades Valley in 1913 in the S. E. ¼ of the S. E. ¼ of section 19, township 19, range 3 W., but the records are not available for publication at the present time.

The hematite production of Alabama for 1913 was 4,370,823 long tons as against 3,814,361 tons for 1912, an increase for 1913 of 556,462 tons or 14.58 per cent. This 1913 production of hematite is 83.58 per cent of the total iron ore production of the State, and 7.05 per cent of the total iron ore production of the United States.

The average price per long ton of hematite in Alabama in 1912 was $1.16; in 1913, $1.18.

Brown Ore or Limonite.

This ore, the second in importance in the State and in the United States, furnished only 2.54 per cent of the total iron ore produced in the United States in 1913. The entire limonite production of the United States in 1913 was 1,577,019 long tons, of which Alabama contributed 844,917 tons, or 53.58 per cent. and the State holds, accordingly, the first rank in this industry.

In the early days of iron making and up to the year 1876 this was the only ore used in the catalan forges, bloomaries, and charcoal furnaces of the State. It was then demonstrated that good iron could be made at low cost from the red ores, with coke for the fuel.

In general the limonites are considered the best of the ores of Alabama and they command the highest prices and command a ready sale.

The usual mode of occurrence is in irregular masses of concretionary origin in the residual clays resulting from the decomposition of limestones, and as a consequence the mining is uncertain and expensive. Limonite also occurs in regularly stratified seams or beds, and then it is the result of the alteration of pyrites or of carbonate ores. Practically all of the brown ore actually mined is that occurring in the residual clays above mentioned. Most of the ore before going to the furnace is washed and screened, and this manipulation, together with the cost of mining, makes it the most expensive of the iron ores, and it is therefore seldom used alone, but is usually mixed with the red ore in porportions determined by the quality of the iron desired. It is used alone in the charcoal furnaces and also in the coke furnaces when a particularly tough pig iron is wanted.

The limonite deposits are very numerous and are distributed over a broad expanse of country and in many places are known to be very extensive. In some of the deposits the ore is in nearly solid mass, in others it is much scattered, and in consequence the amount of foreign material necessary to be moved for every ton of ore produced, varies very much, not only in the different ore banks but also in the different parts of the same bank.

The deposits occur in nearly all the geological formations of the State, but in most of these the ore is either insufficient in quantity or not pure enough to be of much commercial value. The most important of the deposits, in point of extent and value, occur overlying the following formations, viz., the Knox Dolomite and the Weisner Quartzite, the Lauderdale Chert of the Lower Carboniferous, and the Lafayette. Some extensive beds of ore of inferior quality generally occur also in the Tuscaloosa formation of the Cretaceous, and in the upper part of the Lower Carboniferous and in the Metamorphic rocks.

The limonite or brown ore production of Alabama for 1913 was 844,917 long tons as against 749,242 tons in 1912, an increase of 95.675 tons or 12.77 per cent. The average price per long ton of iron ore marketed in Alabama in 1913 was $1.43; in 1913, $1.61.

The following tables show details concerning the production of iron ore in the State, together with the rank of the State in mined and in marketed iron ore, 1912 and 1913.

Iron ore mined in Alabama in 1912 and 1913, by varieties, with percentage of increase in 1913, in long tons.

Year	Hematite	Brown Ore	Total Quantity	Percentage of total U. S. produc'n.
1912	3,814,361	749,242	4,563,603	8.27
1913	4,370,823	844,917	5,215,740	8.42
Increase	556,462	95,675	652,137	....
Percentage of increase 1913	14.58	12.77	14.29	....

Iron ore marketed in Alabama in 1912 and 1913, by varieties, in long tons.

Year	Hematite	Brown Ore	Total Quantity	Total Value
1912	4,012,901	763,644	4,776,545	5,734,871
1913	4,488,176	845,042	5,333,218	6,648,569
Increase	475,275	81,398	556,673	914,198
Percentage of increase	11.84	10.67	11.66	15.94

Rank of first five states in mined and marketed production of iron ore in 1912 and 1913.

1912.

Rank	State	Mined		Marketed			
		Quantity (long tons)	Percentage of total production	Quantity (long tons)	Percentage of total production	Value	Percentage of total value
1	Minnesota	36,431,768	62.43	34,249,813	60.07	$61,805,017	57.74
2	Michigan	11,191,430	20.29	12,797,468	22.44	29,003,163	27.09
3	Alabama	4,563,603	8.28	4,776,545	8.33	5,734,871	5.36
4	New York	1,216,672	2.21	1,167,405	2.05	2,933,026	2.74
5	Wisconsin	860,600	1.56	1,152,250	2.02	2,781,574	2.55

1913.

Rank	State	Mined		Marketed			
		Quantity (long tons)	Percentage of total production	Quantity (long tons)	Percentage of total production	Value	Percentage of total value
1	Minnesota	38,658,793	62.37	36,603,331	61.37	80,789,025	61.72
2	Michigan	12,841,093	20.72	12,668,560	21.24	33,479,954	25.58
3	Alabama	5,215,740	8.42	5,333,218	8.94	6,648,569	5.08
4	New York	1,459,628	2.36	1,420,889	2.38	3,100,235	2.37
5	Wisconsin	1,018,272	1.64	896,243	1.50	2,149,397	1.64

Iron ore mines of Alabama that produced more than 50,000 long tons each in 1913.

Name of Mine	Nearest Town	Variety of Ore	Quantity
1. Red Mountain Group	Bessemer	Hematite	2,205,196
2. Woodward, 1, 2 and 3	Lipscomb	Hematite	586,010
3. Songo	Songo	Hematite	184,118
4. Raimund, No. 1	Bessemer	Hematite	183,638
5. Steinman	Steinman	Hematite	147,313
6. Greeley	Greeley	Brown Ore	127,006
7. Raimund, No. 2	Bessemer	Hematite	117,556
8. Crudup	Gadsden	Hematite	91,001
9. Ironaton	Ironaton	Brown	87,637
10. Raimund, No. 3	Bessemer	Hematite	67,903
11. Houston	Rickey	Brown	67,815
12. Docray	Docray	Brown	67,771
13. Tannehill	Goethite	Brown	62,503
14. Friedman	Woodstock	Brown	56,244
15. Spaulding	Birmingham	Hematite	56,192
16. Attalla	Attalla	Hematite	55,598

Total (16 mines)	4,163,496
Unspecified* (4 mines)	829,197
Tonnage from 20 mines producing more than 50,000 long tons each	4,992,693
Tonnage from 20 mines producing less than 50,000 long tons each	223,047
Grand total of Alabama production	5,215,740

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*Includes the product of 4 mines, producing over 50,000 tons each, operated by 2 companies which do not permit the publication of individual statistics.

PIG IRON.

Quantity and value of pig iron, (exclusive of ferro-alloys) marketed in the United States in 1912 and 1913, (first five States), with increase or decrease and percentage of increase or decrease in 1913, in long tons.

State	1912		1913		Increase (+) or decrease (−) in 1913		Percentage of increase (+) or decrease (−) in 1913	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Pennsylvania	12,437,685	$181,569,299	12,871,349	$197,726,314	+433,664	+16,157,015	+ 3.49	+ 8.90
Ohio	7,127,176	93,140,369	6,913,961	103,824,517	−213,215	+10,684,148	− 2.90	+ 11.47
Illinois	2,806,378	42,828,816	2,892,263	45,796,966	+ 85,885	+ 2,968,150	+ 3.06	+ 6.93
New York	1,973,090	28,059,058	1,967,449	30,203,673	− 5,641	+ 2,144,615	− .29	+ 7.64
Alabama	1,987,758	21,371,053	1,924,762	23,242,374	− 62,991	+ 1,871,321	− 3.17	+ 8.76

Production of pig iron, (including ferro-alloys) in 1912 and 1913, (first five States), in long tons.
Bureau of Statistics of American Iron & Steel Institute.

State	1912			1913	
	Rank	Quantity	Percentage	Quantity	Percentage
Pennsylvania	1	12,552,181	42.28	12,954,986	41.84
Ohio	2	6,802,498	22.88	7,129,525	23.02
Illinois	3	2,887,859	9.71	2,927,882	9.45
New York	4	1,989,281	6.52	2,065,825	6.67
Alabama	5	1,862,681	6.27	2,057,911	6.65

LIME.

EUGENE A. SMITH.

DURING the year 1913 there was a falling off in the production of lime in Alabama as compared with the production of the preceding year. The total product of 12 operators in 1913 was 75,468 short tons, a decrease from the 1912 production of 4,489 short tons or 5.61 per cent. The value of the product was $290,394, a decrease of $7,393, or 2.48 per cent.

The most important use of the lime produced is for building purposes. 40.66 per cent of the State's total production is definitely so credited, while of the 48.74 per cent distributed by dealers and uses not specified a large proportion undoubtedly goes for building purposes so that probably 50 per cent or more of the product is thus used. Other chief uses for lime are in chemical works, paper mills, soap factories, sand-lime brick, slag cement, etc.

In the total above given is included hydrated lime produced at two plants only so that exact figures showing this production cannot be given.

Shelby county as heretofore was the largest producer in 1913, having produced 48,953 short tons, or about 65 per cent of the total. The other producers in the order of their rank were Etowah, Blount, Calhoun and DeKalb.

The following tables present some additional data on the lime production in Alabama in 1912 and 1913:

Production of lime, 1912 and 1913.

	Number of operators	Quantity (short tons)	Rank of State by quantity	Value	Rank of State by value	Average price per ton	Percentage of total U. S. value
1912	13	79,957	14	$297,178	17	$3.72	2.13
1913	12	75,468	16	290,394	16	3.85	1.98
Decrease		— 4,489		— 6,784			
Percentage		5.61		2.28			

Number of lime kilns in Alabama using various kinds of fuel in 1912 and 1913.

Year	Coal	Wood	Coal and Wood	Total Number of Kilns
1912	16	9	27	52
1913	18	0	30	48

Those interested in the subject of lime are referred to an article on lime by Ralph W. Stone of the U. S. Geological Survey, and on the Source, Manufacture, and Use of Lime, by E. F. Burchard and Warren E. Emley of the U. S. Geological Survey, published in Vol. II of the Mineral Resources of the United States for the year 1913.

MICA.

THERE was no production of mica in Alabama during the year 1912, but there was a small production in 1913, but as there was only one producer the figures showing the production cannot be given.

The resources of the State as regards mica are given in the statistical report for 1912. Many important details concerning the production of mica may be found in the Second Volume of Mineral Resources of the United States, in an article by Mr. Douglas B. Sterrett of the U. S. Geological Survey.

MINERAL WATERS.

R. B. DOLE.

RETURNS from Alabama indicate that the mineral-water trade in 1913 was practically the same as in 1912. The sales amounted to 169,687 gallons, or 4,009 gallons more than in 1912, and the value of the output was $19,343, or $1,092 less than in 1912 . The average price reported was 11 cents a gallon, against an average of 12 cents in 1912. Fourteen springs reported sales; one spring active in 1912 was idle in 1913, and one spring's output, which was not reported, was estimated on the basis of the sales in 1912. There was some decrease in the sale of medicinal waters, but an appreciable increase in the sale of table waters, so that trade in the latter found the greater part of the business. Five bathing establishments and resorts accommodating nearly 1,500 guests at 9 springs were maintained. In addition to the quantity reported as sold, 70,000 gallons of mineral water was used in the manufacture of soft drinks.

The following 14 springs reported sales:

Alabama Mineral Springs, McWilliams, Wilcox County.
Bailey Springs, Florence, Lauderdale County.
Bladon Springs, Bladon Springs, Choctaw County.
Blount Springs, Blount Springs, Blount County.
Bromberg Gulf Coast Lithia Spring, Bayou La Batre, Mobile County.
Dixie Spring, Dixie Spring, Walker County.
Healing Springs, Healing Springs, Washington County.
Ingram Lithia Wells, near Ohatchee, Calhoun County.
Livingston Spring Livingston, Sumter County.
Luverne Mineral Spring, Luverne, Crenshaw County.
MacGregor Spring, Spring Hill, Mobile County.
Matchless Mineral Wells, east of Greenville, Butler County.
Purity Spring, Spring Hill, Mobile County.
White Sulphur Wells, near Jackson, Clarke County.

The following table shows the relative productions and their respective values for 1912 and 1913.

Production and value of mineral waters in 1912 and 1913.

	No. of springs reporting	Quantity sold (gallons)	Average retail price	Total value of mineral waters	Percentage of total U. S. value
1912	16	165,678	$0.12	$20,435	0.31
1913	15	169,687	0.11	19,343	0.34
Increase or decrease	− 1	+ 4,009	....	− 1,092	....
Percentage	....	2.42	....	5.34	....

OCHER.

JAMES M. HILL.

OCHER is a hydrated ferric oxide permeating a clay base. It has a specific gravity of about 3.5 and a decidedly golden-yellow color. As viewed under the microscope and with considerable enlargement the particles composing ocher appear flocculent and uniform. Good grades should contain 20 per cent or more of iron oxide, though there is a wide variation in the iron content of the material sold as ocher. Ferruginous shale is often ground and the product marketed as ocher, but unless the material is actually an ocher, as defined above, such product is classed under slate and shale in this chapter.

In 1913 ocher was produced in Georgia, Pennsylvania, Virginia, Alabama, California, Iowa, and Vermont, the States being named in the order of their producing importance. The Georgia output, practically all of which came from the vicinity of Cartersville, Bartow County, was 65 per cent of the total production of the United States. Mines located in Berks, Northampton, and Lehigh counties, Pa., produced a little over 22 per cent of the ocher mined in the country. In Virginia the production was as usual from Page and Pulaski counties. Alabama re-entered the class of ocher producers, a new mine being opened in Clarke County.* The ocher mines of Stanislaus and Calaveras counties, Cal., were worked to a limited extent, and it seems possible, according to trade reports, that the deposits near Michigan Bar, Sacramento County, may be re-opened.

Ocherous clays and true ocher are not unusual in most parts of the country. The Survey is constantly in receipt of samples of yellow material, some of which would undoubtedly make good paints, but many of which are certainly not salable for use as pigments. During the year promising deposits have been opened in Utah, California, and Wisconsin, and several samples have been received from new workings in the old Virginia field.

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*There are many promising deposits of ocher in Alabama, especially in the area of the Tuscaloosa formation of the Cretaceous, as well as in other parts of the Coastal Plain southward nearly to the Gulf. E. A. S.

NATURAL GAS.

BY B. HILL.

NATURAL gas was produced commercially in Alabama in Fayette, Madison, and Walker counties in 1913, there being a total of 340 domestic and 2 industrial consumers supplied in the towns of Fayette, Jasper, and West Huntsville. Jasper was first supplied with gas in 1913, and this is one of the features that mark the progress of the natural-gas industry in this State. As compared with 1912, the number of consumers supplied in 1913 was more than double, and the income derived from sale of gas was proportionately increased.

Considerable effort has been made and much money spent in trying to find an important oil or gas field in Alabama; the results have not been very encouraging, but the prospectors are hopeful, and the work continues. The gas wells in the Fayette and Walker County fields are holding up very well. The number of productive gas wells in the State at the close of 1913 was 18. One well was flooded and abandoned, but an effort will be made to bring it back, and there is a chance that it may yet be a producer. During 1913 there were 7 dry holes drilled in Alabama, 1 in Fayette County, 1 in Morgan County, 4 in Walker County, and 1 in Winston County.

The depth of the productive gas wells in Alabama varies from 300 to 2,400 feet and the pressure from 25 to 800 pounds.

The statistics of the gas production in this State are included with those of Louisiana.

SAND AND GRAVEL.

THE total production of sand and gravel in the State in 1913 was 1,405,068 short tons valued at $398,008, as compared with 852,943 tons valued at $268,111 in 1912, an increase in quantity of 552,125 tons or 64.73 per cent, and an increase in value of $129,977, or 48.48 per cent.

There was an increase in the quantity of sand of 21,686 short tons or 6.11 per cent, but a decrease in value of $767 or 0.6 per cent.

In the quantity of gravel there was an increase of 106.55 per cent, and in the value, of 92.83 per cent.

Over 76 per cent of the sand was used for building purpose.

The following tables give a comparison of production of sand and gravel in 1912 and 1913, and the production, value and disposition of the sand in these two years.

Productions in short tons of sand and gravel in 1912 and 1913.

	Sand		Gravel		Total*		Percentage of total U. S. value
	Quantity	Value	Quantity	Value	Quantity	Value	
1912	355,111	$127,250	497,832	$140,861	852,943	268,111	1.16
1913	376,797	126,483	1,028,271	271,605	1,405,068	398,088	1.64
Increase or decrease	+21,686	— 767	+ 530,439	+130,744	+ 552,125	+129,977	......
Percentage	6.11	.60	106.55	92.83	64.73	48.48	......

*Chert has been added to these totals.

Production (in short tons), value and kinds of sand in 1912 and 1913.

	Molding Sand		Building Sand		Grinding & Polishing Sand		Paving Sand		Engine Sand		Other Sand		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1912	51,107	$25,284	205,498	$66,586	....	....	37,801	$14,997	45,000	$13,300	15,705	$7,083	355,111	$127,250
1913	57,798	23,368	288,346	90,347	25,908	$11,118	2,750	1,250	....	....	2,000	400	376,797	126,483
Increase or decrease	+6,691	−1,916	+82,848	+23,761	....	....	−35,051	−13,747	....	....	−13,705	−6,683	+21,686	− 767
Percentage	13.09	7.58	40.32	35.69	....	....	92.72	91.67	....	....	87.26	94.35	6.11	.60

STONE.

E. F. BURCHARD.

THE figures presented in the following report have to do with the stone produced and sold by the quarrymen and include only such manufactured product as is put on the market by the quarrymen themselves. This applies especially to rough and dressed building stone, dressed monumental stone, crushed stone, flagstone, curbstone, and paving block. The value given to this manufactured product is the price received by the producer, free on board at point of shipment, and includes therefore the cost of labor necessary to dress the stone. The stone reported as sold rough includes stone sold as rough stock to monumental works, and to cut-stone contractors for building purposes; stone sold as riprap, rubble, and flux; and includes the value of only such labor as is required to get the stone out of the quarry in the shape required by the purchaser. The value given to this stone is the price received by the quarryman free on board at point of shipment. In case the stone is sold to local trade the value is given as the quarryman sells the material, generally at the quarry, but in some cases delivered, if this is done by the producer. In some instances a long haul to market or to the railroad increases the cost of the material, and therefore of the selling price.

PRODUCTION.

BY EUGENE A. SMITH.

Alabama produces commercially only three kinds of stone, namely, limestone, marble, and sandstone.

The total value of production of stone in Alabama showed an increase in 1913 of more than 52 per cent. The greater part of this increase was in the limestone production, $281,579 or 53.01 per cent. The sandstone showed a larger per cent of increase, viz., 447.58, though the increase in actual value was less, viz., $123,515. The value of the marble produced also increased in a notable way, but exact figures cannot be given since there were less than three producers.

The following table gives some additional details concerning the total stone production.

Total value of stone (limestone, sandstone and marble) produced in Alabama in 1913. Percentage of total U. S. value, rank of State and number of plants.

Year	Total value	Percentage of total U. S. value	Number of plants	Rank of State
1912	$ 842,300	1.08	26	27
1913	1,285,944	1.54	35	20
Increase 1913	443,644			
Percent increase	52.64			

LIMESTONE.

The most important use of the limestone produced in Alabama in 1913 as in 1912 was for furnace flux, while crushed stone for concrete, and stone for riprap follow next in importance. The very great increase in the percentage of crushed stone used for concrete is the most striking feature in the stone production for the year. There was a very decided falling off in the value of the limestone used for paving, and a decrease less pronounced in the crushed stone used for road making and for railroad ballast. For the first time in many years a production of building stone, rough and dressed, is reported, and the use of limestone for agricultural purposes makes a welcome beginning.

The limestone burned into lime or used in the manufacture of Portland cement is not taken account of here, but is included in the value of each of the finished products in whose manufacture it was used.

As thus limited the total value of the limestone produced in 1913 was $812,664, as compared with $531,085 in 1912, an increase of $281,579 or 43.01 per cent.

The values of the limestone produced in 1912 and 1913, classified according to the uses of the stone, are given in the following table:

Value of limestone (not including marble) produced in 1912 and 1913, according to uses.

Use	1912	1913	Increase or Decrease	Percentage
Rough Building	....	$9,517	+ $9,517	....
Dressed Building	....	27,020	+ 27,022	....
Paving	$15,900	189	− 15,711	98.81
Rubble	....	188	+ 188	....
Riprap	81,361	58,850	− 22,511	27.67
Crushed Stone:				
Road making	54,270	47,237	− 7,043	12.98
R. R. ballast	14,093	7,187	− 6,906	49.00
Concrete	26,235	168,195	+141,860	540.78
Flux	339,166	487,078	+147,912	43.61
Agricultural	60	7,203	+ 7,143	....
Total	531,085	812,664	+281,579	53.01

LIMESTONE FOR BUILDING PURPOSES.

EUGENE A. SMITH.

The preparation of cut stone for building purposes in Alabama, while on the increase, is not yet what it should be. Practically all of this material comes from the quarries in the subcarboniferous limestone of the Tennessee Valley, the most important quarries being at Rockwood in Franklin County, operated by Foster-Creighton-Gould Co., of Nashville. This stone is quite similar in appearance, composition, and other qualities to the Indiana stone, and so far as experience in the use of the stone from the two localities in the buildings of the University of Alabama goes, the Alabama stone holds its own under influence of the weather better than does the Indiana stone. Stone steps, door sills, and window sills, buttress caps, etc., of the Alabama stone put in place in 1885 show practically no deterioration in color and wear under foot, and in crumbling and roughening under the influence of the weather, which cannot be said of some portions of the Indiana stone used in buildings erected in 1909-10. The Rockwood quarries have most modern and approved methods of machinery for sawing the stone and handling it in transit to the mills and elsewhere. The stone is of massive formation, of great thickness and extent. Blocks weighing as much as 25 tons, without crack or flaw, are not infrequently quarried, the size of the blocks being practically limited only by the capacity of the hoisting machinery.

The Oolitic variety is most extensively used for building and monumental work. It is of light gray color, uniform grain, and homogeneous texture. It possesses a quality of cheapness, it can be cut to any design required, and is at the same time strong and durable.

With the installing of adequate machinery at the quarry for doing the finished work, there should never be any longer any reason for going outside of the State for this quality of stone. Already the material has been very extensively used in public buildings in Mississippi, Tennessee, as well as in Alabama. The only reason why it was not used in the recently erected buildings at the University of Alabama was that at the time these building contracts were let, the quarries furnished only the rough sawn stone and there was not in Alabama any establishment adequately equipped for the dressing of the stone in the quantity needed.

MARBLE.

EUGENE A. SMITH.

The marble of Alabama is of two kinds, crystalline or true marble and non-crystalline.

The crystalline or statuary marble occurs mainly in a narrow valley along the western border of the metamorphic area, extending from Marble Valley in Coosa County, through Talladega into Calhoun. The length of the marble belt through Coosa and Talladega counties is about 50 miles. The width of the valley carrying the marble as a rule is from one quarter to one-half mile, widening in places to a mile and a quarter, for example in the neighborhood of Sylacauga.

The quarries longest known are Gantt's and Herd's near Sylacauga, Nix's near Sycamore, Bowie's near Rendalia, and Taylor's and McKenzie's near Taylor's Mill, east of Talladega. From all of these marble was quarried before the civil war.

During 1913 only two companies reported any marble production, viz., the Alabama Marble Company, at Gantt's Quarry and the Moretti-Harrah Company, whose quarry adjoins Gantt's.

The Alabama Marble Quarries of the Scott Brothers near Sycamore and the Eureka Quarry near Talladega Springs are in course of development and will report production in 1914.

The plant of the Alabama Marble Company at Gantt's Quarry which was completely destroyed by fire in December, 1910, has been rebuilt and equipped with all the machinery needed for the working up of any kind of finished product.

I think it is fairly safe to say that on the whole the marble from this quarry and immediate vicinity is of the highest grade of commercial white marble now on the market and obtainable in large quantity. There are small quantities of marble produced both in Italy and Vermont that are somewhat freer from coloring matter than the best grades that can be produced in Alabama in any quantity. But on the other hand, the poorest grades in Alabama greatly surpass the poorest grades produced elsewhere, so that the average of the Alabama deposit is probably somewhat higher than that of any other so far developed, not excluding even the marble from the Carara district in Italy. The marble from this State (Gantt's Quarry) has now a well established reputation and has been used in more than 200 important buildings throughout the United States.

It can be seen in the galleries of the National Museum in Washington.

A beautiful quality of variegated limestone or marble—red, pink and white—belonging probably to the Cambrian formation, occurs in Shelby County a mile or two south of Shelby Springs station on the L. & N. railroad, and extending thence southwest for a mile or two. Nothing but prospecting work has been done on this marble. The Trenton limestone in the Appalachian valleys, particularly Jones Valley below Bessemer, contains marble similar to that quarried in the vicinity of Knoxville, Tenn. Also as to Pratt's ferry on the Cahaba River in Bibb County a quarry was for many years worked in this formation and turned out a very beautiful quality of marble varying in color from gray through pink, red and brown shades.

A black marble which is exceedingly promising, has been reported and some development work done near Anniston, and at Piedmont, Calhoun County, and some very handsome specimens of cave onyx have been obtained from near Kymulga in Talladega County.

In the Coastal Plain the St. Stephens limestone of the Tertiary holds ledges of hard, almost crystalline rock capable of taking good polish. The colors vary from nearly white, through shades of yellowish into red, and it would make a handsome decorative marble, especially for inside work.

Other limestone formations, such as the Subcarboniferous and the Knox Dolomite, could in places be drawn upon for marble.

No figures of production of marble can be given as there were only two companies reporting. The greater part of the product was used for interior decoration.

SANDSTONE.

As may be seen in the tables below, the production of sandstone in 1913 shows a very marked increase in value along every line and particularly in the crushed stone used in concrete. The total value of the sandstone production of 1913 was $151,111, as compared with $27,596 in 1912, an increase of $123,515, or 629.1 per cent.

Value of sandstone production in Alabama from 1909 to 1913.

Year	1909	1910	1911	1912	1913
Value	$77,327	$109,063	$78,195	$27,596	$151,111

Value of sandstone production in Alabama in 1912 and 1913, according to uses.

Uses	1912	1913	Increase or Decrease	Percentage
Rough Building	....	$37,500	+$37,500	....
Ganister	$45	....	— 45	....
Rubble	$4,866	9,055	+ 4,189	86.09
Riprap	10,685	17,056	+ 6,371	59.62
Crushed Stone:—Concrete	12,000	87,500	+ 75,500	629.17
Total..	27,596	151,111	+123,515	447.58

SUMMARY.

BECAUSE of the difference in the units of measurement employed in the various branches of the mineral industry, a summation of the production of the year can include only the values of the products. It is also to be noted that a simple summation of all the values of the minerals or mineral products listed in this pamphlet would give a value much in excess of the true value, since in many cases, as, for instance, coal and coke, and iron ore and pig iron and steel, the second product is directly a product of the first, and the value of the first is included in that of the second. To give the values of both as a part of the total would be to repeat, in a measure, at least a partial value of the first or raw product, and would give an erroneous result.

As the Survey has not, however, the figures upon which to base an estimate as to the percentage of each product which was used in the manufacture of some other product, the summation of the mineral production of the State, as given here, will be a simple summation of the values reached by the individual branches of the industry.

According to this rather unsatisfactory manner of summation, which does not include the value of the steel produced, the value of the 1913 raw mineral and immediately derived products was $67,530,089, as compared with $60,141,793 in 1912, an increase of $7,388,296, or 12.28 per cent. This production may be classified as follows:

Raw products	**$34,660,545**
Pig iron	**23,242,374**
Coke	**9,627 170**
Total	**67,530,089**

The more important mineral products after coal, pig iron and coke, in the order of their value, are iron ores, clay products, stone, cement, sand and gravel, and lime.

Below is a tabular presentation of the value of the mineral productions as estimated above for 1910, 1911, 1912 and 1913:

Total value of the mineral production and products in Alabama in 1910, 1911, 1912, and 1913.

Year	Value
1910	$63,207,945
1911	52,772,951
1912	60,141,793
1913	67,530,089

GEOLOGICAL SURVEY OF ALABAMA

EUGENE ALLEN SMITH, *State Geologist*

BULLETIN No. 16.

STATISTICS OF THE MINERAL PRODUCTION OF ALABAMA FOR 1914

COMPILED FROM MINERAL RESOURCES OF THE
UNITED STATES

By
EUGENE A. SMITH

UNIVERSITY, ALABAMA
1915

PRESS
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ALABAMA

LETTER OF TRANSMITTAL.

UNIVERSITY, ALA., December, 1915.

HON. CHARLES HENDERSON,
Governor of Alabama,
Montgomery, Ala.

SIR:—I have the honor to transmit herewith the manuscript of a Report on the Mineral Production of Alabama for the year 1914 with the request that it be printed as Bulletin No. 16 of the Geological Survey of Alabama.

Very respectfully,

EUGENE A. SMITH,
State Geologist.

GEOLOGICAL CORPS.

Eugene Allen Smith, Ph. D.	State Geologist
William F. Prouty, Ph. D.	Chief Assistant
Robert S. Hodges	Chemist
Herbert H. Smith	Curator of Museum
Roland M. Harper, Ph. D.	Botanist
A. T. Donoho	Stenographer
Geo. N. Brewer	Field Assistant

RIVER GAGE HEIGHT OBSERVERS.

C. J. Stowe	Jacksons' Gap, Tallapoosa River
J. E. Whitehead	Riverside, Coosa River
S. T. Dillard	Beck, Conecuh River
Ed. Bullen	Red Bay, Big Bear Creek

From the records of daily observations of the gage readings at these places when extended through sufficient time, the calculations of available horsepower to be obtained from the different streams is made.

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PREFACE.

The statistics of all the minerals included in the following pages have been collected in cooperation with the United States Geological Survey, and have been compiled from advance chapters of the *Mineral Resources of the United States,* a publication of the Federal Survey.

The introductory and general matter in each of these articles has either been taken without change from the U. S. advance chapters or has been rearranged or condensed from these chapters, or entirely rewritten to suit it for our present purposes. In each case credit is given to the author.

INTRODUCTION.

EUGENE A. SMITH

AN INSPECTION of the subjoined table will show that there has been a decided decrease in the value of all the mineral products of Alabama in 1914 except cement, gold and silver, graphite and stone, (including marble). The statistics also show that there has been a corresponding decrease in the value of the mineral products of the United States as a whole.

In Bulletin No. 15 of the Alabama Geological Survey,—Statistics of Mineral Production in the State in 1913,—there is an admirable general discussion by Mr. E. W. Parker of the U. S. Geological Survey, of the Mineral Production of Alabama from the early days to the year 1913, along with specific details of the production in 1912 and 1913.

Following the plan thus set out by Mr. Parker, we pass in review the production in 1913 and 1914 of Alabama minerals and their immediate derived products, taking them up somewhat in the order of their commercial importance.

Coal.—Alabama's production of coal in 1914 was 15,593,422 short tons, valued at $20,849,919, a decrease of 11.8 per cent in quantity and 9.68 per cent in value in 1914 as compared with 1913. As in 1913 the value of the coal product of Alabama in 1914 is approximately two-thirds that of the total mineral output.

Coke.—The coke production of Alabama decreased from 3,323,664 short tons valued at $9,627,170 in 1913, to 3,084,149 tons valued at $8,408,443 in 1914, a decrease in value of $1,218,727 or 12.66 per cent.

Iron Ore and Pig Iron.—While there was in 1914 a decrease of 7.22 per cent in quantity of the total iron ore production, and of 10.71 per cent in the quantity of the Hematite, there was an increase in the quantity of brown ore, of 10.83 per cent. In the quantity of pig iron marketed in Alabama in 1914 there was a decrease from 1913 of 13.68 per cent and a decrease in the value of 24.78 per cent.

The value of this iron ore production and not the value of the pig iron is used in making up the total value of the mineral products of the State.

The total value of the mineral production of Alabama, excluding the value of the pig iron and coke and including the value of the iron ores, was $30,879,288 in 1914, compared with 34,660,545 in 1913, of which, as already stated, approximately two-thirds is represented by the output of the coal mines. Nearly one-fifth of the total value was contributed by the iron mines. The decrease in 1914 from 1913 was $3,781,257, or 10.9 per cent.

The principal coal producing counties are Jefferson, Walker, Bibb, Tuscaloosa and St. Clair in the order named. The principal iron ore counties are Jefferson, Tuscaloosa, Franklin and Etowah. The combined value of the pig iron and coke made in Alabama approximates $26,000.00. These values are not included in the total as they are represented in the value of the iron ore and coal produced.

Clay-Working Industries.—These industries yielded products in 1914, valued at $1,574,023 against $2,091,581, in 1913, a decrease of $17,558, or nearly 25 per cent. This does not include the value of the raw clay sold, which in 1914 amounted to $34,607, a decrease from 1913 of 35.03 per cent.

The center of the clay-working industry is Jefferson county, and Birmingham furnishes the principal market. Vitrified, front and fire brick represent a value of $495,398 or 77.7 per cent of the value of the common brick, while the total output of the brick yards makes up over 72 per cent of the State's total clay products. All of the fire brick is reported from Jefferson county and all of the vitrified brick is from Jefferson and St. Clair counties. Clay pits for the manufacture of common brick have been opened in one or more places in 30 different counties.

Stone.—The quarry products, the larger part of which is limestone, were valued in 1914 at $1,319,753, an increase of 2.63 per cent from $1,285,944 in 1913.

The increased production in 1914 was in the output of limestone for rough building stone, road making, concrete and for agricultural purposes; for sandstone used in Government works on the Warrior River, and the production of marble.

Over 87 per cent of the total value of the stone production is limestone. Its most important uses are for furnace flux, concrete, road making, for building purposes and for agricultural uses. While heretofore comparatively little of the Alabama limestone was used for building purposes, there has been in 1914 a remarkable increase, 119.5 per cent along this line. In the production of marble there has also been a notable increase in 1914. The reader is referred to the body of this Bulletin under Stone for further details concerning especially the building stone and marble industries.

Marble holds the second place in the value of quarry products, a beautiful white marble occurring in Coosa and Talladega counties being extensively used for building (both inside and outside work), and a black marble which gives promise of future development, has been prospected near Anniston and near Piedmont.

Cement.—The cement production of Alabama amounted in 1914 to 777,698 barrels, valued at $746,555, as against 823,246 barrels in 1913 valued at $685,422, a decrease of 5.53 per cent in quantity but an increase in value of 8.92 per cent.

Lime.—The lime production is not included in that of the limestone, and amounted to 46,966 short tons, a decrease from 1913 production of 28,502 short tons, or 37.77 per cent. The value of the product was $199,814, a decrease of $90,580 or 31.19 per cent.

Graphite.—The Alabama graphite is all of the crystalline variety, and the value of the product in 1914 was $118,000 as against $87,336 in 1913, an increase of 35.88 per cent. The Alabama production for 1914 was 41.35 per cent of the total value of the crystalline graphite produced in the United States, and 36.46 per cent of the total value of amorphous and crystalline combined. The great increase in production in 1914, and the installing of a number of new plants, not in active operation during 1914, makes it probable that the Alabama production in 1915 and following years will represent an even larger proportion of the U. S. total value.

Minor Products.—Alabama produces a small quantity of gold and silver, and other minor products are bauxite, mica, millstones, mineral paints, (natural pigments), mineral waters, natural gas, and sand and gravel.

In the following table is presented a comparison of the mineral output of Alabama in 1913 and 1914. As stated above, the total does not include the value of pig iron or that of coke, but it does include the value of the coal made into coke and of the iron ore sold or used.

Mineral production of Alabama in 1913 and 1914.

	1913				1914			
	Raw		Derived		Raw		Derived	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Barytes, short tons	....	....	....	....	*	*	....	....
Bauxite, long tons	*	*	....	....	*	*	....	....
Cement, barrels	....	....	823,246	$685,422	....	†	777,698	$746,555
Clay products, short tons	49,901	$58,419	....	2,091,581	27,978	$34,607	....	1,574,028
Coal, short tons	17,678,522	23,083,724	....	....	15,593,422	20,849,919	....	....
Coke, short tons	....	....	3,323,664	†9,627,170	....	....	3,084,149	†8,408,443
Ferro alloys, long tons	....	....	....	....	....	....	*†	*†
Gold, fine ounces (troy)	....	....	587	11,094	....	....	579	11,970
Graphite, crystalline, pounds	2,020,910	87,386	....	....	2,410,200	118,000	....	....
Iron ore, long tons	5,388,218	6,648,569	....	....	4,514,926	5,727,619	....	....
Iron, pig, long tons	....	....	1,924,762	†23,242,374	....	....	1,661,420	†17,481,828
Lime, short tons	....	....	75,468	290,394	....	....	46,966	199,314
Mica	....	....	....	*	....	....	....	*
Millstones	....	....	....	*	....	....	....	*
Mineral paints, natural pigments, short tons	....	....	*	*	....	....	*	*
Mineral waters, gallons sold	169,687	19,348	....	....	169,279	17,125	....	....
Natural gas	....	*	....	....	....	*	....	....
Sand and gravel, short tons	1,405,068	398,088	....	....	831,430	262,219	....	....
Silver, fine ounces (troy)	....	....	117	71	....	....	199	110
Stone	....	‡	....	‡1,285,944	....	‡	....	‡1,319,758
Miscellaneous	....	46,618	....	12,361	....	42,382	....	336,325
Total value, eliminating duplications	$34,660,545				$30,879,288			

* Value included under "Miscellaneous." † Value not included in total value. ‡ Stone sold rough included in derived products.

STATISTICS OF THE MINERAL PRODUCTION OF ALABAMA FOR 1914.

ABRASIVES.

EUGENE A. SMITH.

ALABAMA'S production of abrasives is at present limited to a small number of millstones (chasers*) quarried and made at Dutton, Jackson County; there are, however, several materials in different parts of the State which are sufficiently promising to be worth investigation and thorough testing; the nature and locality of these deposits were treated in Bulletin No. 13, which see.

BARYTES.

JAMES M. HILL.

There has been no production of barytes in Alabama since 1906 until 1914, when a small production is reported from Calhoun county. There are other deposits which probably could be worked with profit in Etowah, St. Clair and Bibb counties.

The residual deposits so far worked are associated with the Chickamauga ("Pelham") limestone, of Ordovician age, and the Knox dolomite, of Cambrian and Ordovician age. They seem to be localized along lines of folding and faulting of the rocks, particularly along the eastern side of the Appalachian fold. The barytes probably occurred originally as veins and replacements along fissured or fractured dolomite. Solution of the dolomite has left the insoluble barium sulphate in nodules and bowlders in the residual clay.

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*Chasers are larger than the regular millstones. They are used for heavier work, such as grinding quartz, feldspar, barytes, etc., and they run on edge. Though they are made with a diameter as short as 24 inches, they are usually turned out with diameters ranging from 50 to 84 inches, and are as much as 22 inches in thickness. These chasers are run on pans paved with roughly cubical blocks of the conglomerate, with edges about a foot in length. In grinding quartz in such pans the chasers are used in the preliminary crushing; then rough blocks, usually three in number, are either attached to or carried along by lateral arms, which in turn are joined to a vertical revolving shaft. By the circular movement of these blocks the material placed in the pan is ground to powder.

There were 14 operators in New York in 1912. One quarry was reported idle during the year and one former operator has gone out of business.—Frank J. Katz.

CHARACTER OF BARYTES.

Barytes, or heavy spar ($BaSO_4$), is composed of 65.7 per cent barium oxide (BaO) and 34.3 per cent of sulphur trixoide (SO_3). The specific gravity of the mineral ranges from 4.3 to 4.6; its hardness varies from 2.5 to 3.5. It is usually a white opaque to translucent crystalline mineral about as hard as calcite, but it differs from calcite in its greater specific gravity and in the fact that it is perfectly inert when treated with acids. Some barytes is stained reddish pink or yellow by iron oxide. In its common form it is an aggregate of straight or slightly curved cleavable plates, but it occurs also in granular, fibrous, and earthy masses, and in the form of stalactites, as well as in single and clustered crystals. Natural barytes is rarely pure, its most common impurities being silicia, lime, magnesia, and the oxides of iron and aluminum. Fine particles of galena are disseminated through many of the deposits in the United States. The commercial grades of the mineral as mined carry 95 to 98 per cent barium sulphate and 1 to 3 per cent of silica.

USES OF BARYTES.

Barytes is used principally as a pigment in mixed paints, in the manufacture of lithopone—a chemically prepared white pigment consisting of zinc sulphide and barium sulphate—and as a base upon which the lake pigments are precipitated. It is also used in the manufacture of white rubber goods, asbestos cement, and artificial ivory, and in the preparation of fertilizers, boiler compounds, insecticides, peroxide of hydrogen, and artificial driftwood salts. Barium carbonate and some barium chloride are used to prevent efflorescence on bricks; and the carbonate, sulphate, or nitrate is used in the manufacture of rolled glass, hollow glass, crystal and table glass, and in special glasses such as the Jena phosphate crown glass.

BAUXITE.

The production of bauxite in Alabama for 1914 was limited to one producer, which accounts for the decrease and also for the joining of the Alabama and Georgia totals.

The following table gives the production and value of bauxite from 1889 to 1914, inclusive:

Production of bauxite in the United States, 1889-1914, by States, in long tons.

Year	Georgia	Alabama	Arkansas	Total	Value
1889	728	....	....	728	$2,866
1890	1,844	....	....	1,844	6,012
1891	3,301	292	....	3,593	11,675
1892	5,110	5,408	....	10,518	34,183
1893	2,415	6,764	....	9,179	29,507
1894	2,050	9,016	....	11,066	35,818
1895	3,756	13,313	....	17,069	44,000
1896	7,313	11,051	....	18,364	47,338
1897	7,507	13,083	....	20,590	57,652
1898	....	....	....	25,149	75,437
1899	15,736	14,499	5,045	35,280	125,598
1900	19,739		8,445	28,184	89,676
1901	18,038		867	18,905	79,914
1902	22,677		4,645	27,322	120,366
1903	22,374		25,713	48,087	171,306
1904	21,913		25,748	47,661	235,704
1905	15,173		32,956	48,129	240,292
1906	25,065		50,267	75,332	368,311
1907	....		....	*97,776	480,330
1908	14,464		*37,703	52,167	263,968
1909	22,227		*106,874	129,101	679,447
1910	33,096		*115,836	148,932	716,258
1911	30,170		*125,448	155,618	750,649
1912	19,587	14,173	*126,105	159,865	768,982
1913	27,409		*182,832	210,241	997,698
1914	18,547		200,771	219,318	1,069,194

*Production of Tennessee included.

For an outline of the uses of bauxite, see Bulletin No. 13.

The Republic Mining & Manufacturing Co. was the only one that operated in Alabama in 1914. The company worked near Rock Run, Cherokee County, in the eastern part of the State.

CEMENT.

EUGENE A. SMITH.
E. F. BURCHARD.

PUZZOLAN OR SLAG CEMENT.

DURING the past six years only one establishment in Alabama has been engaged in the manufacture of slag cement, using the material from the furnaces about Birmingham. The production is included in the returns for Portland cement and cannot be given separately.

PORTLAND CEMENT.

RESOURCES.

Alabama contains large supplies of limestone, chalk, clay and shale well adapted for Portland Cement manufacture, and widely distributed throughout the State. Coal and labor are abundant and cheap, transportation facilities are excellent, and many of the best limestone and chalk localities are situated on navigable rivers, giving ready access and cheap water transportation to Galveston, New Orleans, Mobile, Charleston, and other ports of the Gulf and Atlantic Coasts. This advantage of location was immensely increased with the opening of the Panama Canal for cement plants located in Alabama are more than a thousand miles nearer to the Isthmus than their nearest possible competitors.

The limestones and shales of the northern part of the State lie so close to each other, and above all so close to the great coal mines which must supply the fuel, that the establishment of Portland Cement plants near the coal mines would give to this industry in Alabama the same advantages which the proximity of the iron ore, the coal, and the stone has given to the iron industry, and which has placed our State beyond competition.

As a Portland cement mixture, ready for burning, consists approximately of 75 per cent lime carbonate and 25 per cent of clayey matter, the material furnishing the lime carbonate is necessarily of more economic importance than that from which the silica and alumina are derived. In consequence, a Portland cement plant is usually located in the immediate vicinity of a suitable limestone, while the clay or shale required to complete the mixture may be brought some distance.

The limestone formations in North Alabama which can supply the stone adapted for use in cement manufacture are the Trenton or Pelham limestone and the Bangor or Subcarboniferous. In close proximity to both these limestone formations are the shales of the Clinton, Subcarboniferous and Coal Measures.

At the present time there are two cement plants in North Alabama, namely, the Standard Portland Cement Co., located at Leeds in Jefferson County, and the Atlantic & Gulf Portland Cement Co., located at Ragland in St. Clair County. Both of these plants make use of the hard Trenton limestone, and the Standard Cement Co., according to Burchard of the U. S. Geological Survey, uses the shale of the Clinton formation whilst the Ragland Company makes use of the shales of the Coal Measures. Up to the present time no establishment is utilizing the Bangor limestone.

In Middle Alabama the soft, chalky Cretaceous limestone of the Selma Chalk, is the material utilized by the Alabama Portland Cement Co., at Spocari, near Demopolis. The same Company makes use of residual clays overlying and derived from the weathering of the Selma Chalk. During 1914 there was no production reported from the Demopolis plant.

In Southern Alabama the St. Stephens limestone outcropping east and west across the State, furnishes excellent material for Portland Cement manufacture, using either residual clays from decomposition of the limestone, or the clays of the Grand Gulf formation which are almost everywhere in close proximity to the limestone*

The following tables summarize the number of active plants in the United States, and the production of puzzolan cement during the last five years; and the production and value of cement (including puzzolan and Portland) in Alabama in 1913 and 1914:

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*Since recent investigations (quoted by Burchard), have shown that limestones containing as much as 10 per cent of magnesia, (MgO), may be used in the manufacture of Portland cement, without detriment to the quality of the cement, the quantity of limestone in Alabama suitable for this manufacture is very greatly increased, over former estimates.—E. A. S.

Statistics of the puzzolan cement industry, 1910-1914.

	1910	1911	1912	1913	1914
Number of plants reporting production:					
Alabama	1	1	1	1	1
Indiana	0	0	0	0	1
New York*	....	1	1	1	1
Ohio	2	1	1	1	1
Pennsylvania	1	1	1	1	1
Total	4	4	4	4	5
Production in barrels of 380 pounds	95,951	98,280	91,864	107,913	68,811
Value of production	$68,286	$77,786	$77,863	$97,663	$63,358

*Includes production of Collos cement in 1911, 1912, and 1913.

Owing to the fact that there was in Alabama in 1914 only one producer of puzzolan cement, and not more than two operating plants in the Portland cement industry, it is necessary to combine the productions of the two industries in order to avoid publishing figures which were given to the survey in confidence. The tabular results of such a combination are, however, necessarily inconsistent and not to be taken too literally, since the weights per barrel of the two kinds of cement vary.

The total quantity of Portland and puzzolan cement produced in Alabama in 1914 was 777,698 barrels, valued at $746,555, as compared with 823,246 barrels in 1913, valued at $685,422, or a decrease in the production of 45,548 barrels, or 5.53 per cent, but an increase in value of $61,233, or 8.92 per cent.

Below are presented in tabular form the foregoing figures:

Production and value of cement (including puzzolan and Portland) in Alabama in 1913 and 1914.

	No. of Producers	Quantity (Bbls.)	Value	Percentage of total U. S. Value
1913	3	823,246	$685,422	0.74
1914	3	777,698	746,555	0.93
Decrease and increase	....	—45,548	+61,133	....
Percent. of increase and decrease	....	—5.53	+8.92	....

In "Mineral Resources of the United States, for 1914, Part II, (pages 221-259)," the reader, who is interested in the subject, will find a very complete presentation of the cement industries of the United States, by Mr. E. F. Burchard of the U. S. Geological Survey.

CLAY AND CLAY PRODUCTS.

JEFFERSON MIDDLETON AND EUGENE A. SMITH.

CLAY.

CLAY available for the manufacture of clay products is one of the most widely distributed of our minerals. Hence there are clay-working plants scattered over every State and Territory in the Union. Miners of the lower-grade clays are usually also the manufacturers, but as the higher grades of ware are reached, the rule is that fewer and fewer manufacturers are also miners, until in the highest grades of ware the rule is that the manufacturer buys and does not mine the clay he uses. The figures given in the following tables represent clay that is mined and not manufactured by the miner, but is sold as clay. The clay thus sold is small in quantity compared with the total production and includes mainly clay used for high-grade pottery and tile, for paper making, and for refractory products.

The total amount of clay mined in Alabama and sold as such in 1914 was 27,973 short tons, valued at $34,607. This was a decrease in quantity of 21,928 tons, or 43.93 per cent, and of $18,662, or 35.03 per cent in value as compared with 1913.

Below is a table giving the production and value of clay mined and sold in Alabama from 1908 to 1914 inclusive, and a comparison of the production of 1913 and 1914.

Production of clay in Alabama from 1908 to 1914 inclusive, and a comparison of the production in 1913 and 1914.

YEAR	Fire Clay		Miscellaneous Clay		Total	
	Quantity Short Tons	Value	Quantity Short Tons	Value	Quantity Short Tons	Value
1908	68,289	$48,983	24,000	$12,000	92,289	$60,983
1909	45,137	35,345	18,271	5,587	63,408	40,932
1910	54,482	32,395	20,600	5,650	75,082	38,045
1911	35,208	29,909	....	....	35,208	29,909
1912	38,552	31,414	4,500	2,000	43,052	33,414
1913	49,901	53,269	*	*	49,901	53,419
1914	27,973	34,607	....	....	27,973	34,607
Decrease 1914	21,928	18,662	....	....	21,928	18,812
Percentage of Decrease	43.93	35.03	....	....	43.93	35.21

*Not divulged but included in total.

In 1913 the average value of fire clay was $1.07 per short ton and the fire clay production of Alabama represented 1.21 per cent of the total value of the United States production. In 1914 the average value of Alabama fire clay was $1.22 per short ton, and the value of the Alabama product was 0.92 per cent of the total value of the fire clay produced in the United States.

CLAY WORKING INDUSTRIES.

ALABAMA, like others of the Southern States, is rich in clays, but its rank as a clay-working State is not very high. In 1914 it was twentieth among the States, with products valued at $1,574,023, or less than 1 per cent of the total. This was a decrease of $517,558, or nearly 25 per cent from 1913. Alabama was tenth in the production and value of vitrified paving brick. The principal product was common brick, valued in 1914 at $638,666 and representing 40.58 per cent of the value of all of Alabama's clay products in that year.

Jefferson County was the principal clay-working county, reporting a production valued at $1,029,135, or 65.38 per cent of the total value for the State in 1914, a decrease of $284,297 from 1913. Nearly all of the fire brick produced in the State comes from Jefferson County and fire brick and vitrified brick are its principal clay products. The leading counties in the value of common brick in 1914 were, in the order of their importance, Jefferson, Montgomery, Russell, and Talladega.

Clay products of Alabama, 1910-1914.

Product.	1910	1911	1912	1913	1914
Brick:					
Common—					
Quantity	135,785,000	129,694,000	136,989,000	130,928,000	110,731,000
Value	$746,961	$708,903	$759,409	$730,148	$638,666
Average per M	$5.50	$5.47	$5.54	$5.58	$5.77
Vitrified—					
Quantity	19,772,000	21,444,000	26,480,000	24,183,000	18,679,000
Value	$236,516	$246,707	$353,303	$361,722	$248,525
Average per M	$11.96	$11.50	$13.34	$14.96	$13.31
Front—					
Quantity	(*)	9,169,000	10,629,000	(*)	(*)
Value	(*)	$128,403	$132,033	(*)	(*)
Average per M	$15.96	$14.00	$12.42	$15.29	$11.42
Fancy, value	....	(*)	(*)	....	(*)
Fire, value	$163,672	$193,375	$240,434	(*)	$167,021
Draintile, value	$3,773	$3,777	$5,465	$10,802	$6,838
Sewer pipe, value	(*)	(*)	(*)	(*)	(*)
Fireproofing, value	(*)	(*)	(*)	(*)	(*)
Tile, not drain, value	....	....	....	(*)	....
Pottery:					
Red earthenware, value	$3,475	$11,243	$10,990	$11,164	$4,800
Stoneware and yellow and Rockingham ware, value	$16,371	$14,753	$11,223	$8,994	$11,742
Miscellaneous, value	$496,791	$639,941	$422,322	$968,751	$496,431
Total value	$1,667,559	$1,947,102	$1,935,179	$2,091,581	$1,574,023
Number of active firms reporting	87	82	74	68	70
Rank of State	22	17	17	16	20

*Included in "Miscellaneous."

BRICK AND TILE.

THE total production of common brick in Alabama in 1914 was 110,731 M, valued at $638,666. This as compared with the 1913 production, represents a decrease in both quantity and value, of 20,192 M or 15.34 per cent, and of $91,482, or 12.53 per cent, respectively.

In the case of vitrified brick there was also a decrease in quantity of 5,504 M, or 22.76 per cent, and in value of $113,197 or 31.29 per cent.

In 1913 the number of producers of fire-brick in Alabama fell below 3, and the quantity and value could not be disclosed. In 1914, however, the production was 8,721 M, valued at $167,021.

The following table gives a review of the brick and tile industry in Alabama for 1913 and 1914.

Production of brick and tile in Alabama in 1914, not including pottery products.

Kind	Quantity per Thousand	Value	Average Value per Thousand	Percentage of total value of brick and tile	Percentage of total U. S. value
Common brick	110,731	$638,666	$5.77	41.01	1.45
Vitrified Brick	18,679	248,525	$13.31	15.96	1.98
Drain Tile	....	6,838	....	0.43	.08
Fire Brick	8,721	$167,021	$19.15	10.73	1.01
Miscellaneous	....	*496,431	....	31.87	....
Total	....	$1,557,481	....	100.00	1.20

*Includes front brick, fancy brick, sewer pipe, fire-proofing, and silica brick.

Brick and tile production in 1913 and 1914 compared.

Kind	1913			1914			Increase or Decrease in Value	Percentage
	Quantity M	Value	Average Price	Quantity M	Value	Average Price		
Common Brick	130,923	$730,148	$5.58	110,731	$638,666	$5.77	— $91,482	12.53
Vitrified Brick	24,183	361,722	14.96	18,679	248,525	13.31	—$113,197	31.29
Front Brick	*	*	15.29	*	*	*11.42		
Fire Brick	*			8,721	$167,021	19.15		
Drain Tile		10,802			6,838		— $3,964	36.69
Miscellaneous		†968,751			†496,431			

*Included in Miscellaneous.
†Includes front brick, fancy brick, sewer pipe, fire proofing, and silica brick.

POTTERIES.

THE pottery industry of Alabama is of relatively small importance, as only the commoner and coarser grades of ware are produced and most of this for local trade only.

Production was reported for 1914 by 13 operators, an increase of 4. The output was valued at $16,542, a decrease of $3,616 or 17.94 per cent. The products consisted of red earthen ware and stone ware only. The rank of Alabama in this industry for 1914 is 19.

The following tables show the values of the pottery product in 1914 and a comparison of the production and values for the years 1913 and 1914.

Value of pottery products in 1914.

Kind	Value	Percentage of total Alabama Pottery's Products	Percentage of total U. S. Value
Red Earthenware	$4,800	29.02	.45
Stoneware and Rockingham ware	$11,742	70.98	.35
Total	$16,542	100.00	.05

Comparison of pottery products in 1913 and 1914.

Kind	1913	1914	Increase+ or Decrease—	Percentage
Red Earthenware	$11,164	$4,800	—$6,364	57.00
Stoneware and Rockingham ware	8,994	11,742	+ 2,748	30.55
Total	$20,158	$16,542	--$3,616	17.94

COAL.

E. W. Parker and C. E. Lesher.

Introductory.

THE great Appalachian coal region which furnishes over two-thirds of the coal production of the United States and which extends from Ohio and Pennsylvania on the north in a gradually narrowing belt through eastern Kentucky and Tennessee has its southern terminus in a considerably broadened area that occupies a large part of the northern half of Alabama. The coal-bearing formations of Alabama underlie about 8,400 square miles and are divided into four distinct basins, the Coosa, the Cahaba, and the Warrior, named from the rivers which drain them, and the Plateau, which includes Blount, Lookout, and Sand or Raccoon Mountains. By far the most important basin in area and in production in the Warrior, which includes all of Walker County, most of Jefferson, Tuscaloosa, and Fayette counties, and smaller parts of Blount, Cullman, Winston and Marion counties. The area known to contain coal is approximately 4,000 square miles, or one-half the total coal area of the State, and contributes about 81 per cent of the total production.

There are several distinct coal groups in the basin, the most important of which are the Brookwood, the Pratt, and the Mary Lee, designated by the names of their principal beds. The Mary Lee group includes the Blue Creek, the Jagger, and the Newcastle beds, most of which are mined in places. The Brookwood, the Pratt, and the Mary Lee produce most of the coking coal mined in the State, and more than half of all of the coal mined in the district.

The Cahaba Basin, second in importance, is a long narrow syncline, 68 miles long and about 6 miles wide, southeast of the Warrior, and occupies parts of St. Clair, Jefferson, Shelby, and Bibb counties. There are many workable beds, and the total quantity of coal in the basin is large. The production is something over 18 per cent of the total for the State.

The Coosa Basin is a deep syncline east of the Cahaba and parallel with it, extending across Shelby and St. Clair counties. It is also long and narrow, 60 miles long by 6 miles wide. It has not been thoroughly explored, but in different parts of the area from two to twelve beds, 3 or more feet in thickness, have been reported.

The Plateau field embraces parts of Blount, Etowah, DeKalb, Cherokee, Marshall, and Jackson counties, and although it has an area underlain by coal four times that of the Cahaba and the Coosa combined, the resources in Alabama are comparatively small. There are four to six beds locally workable. So far as known, the earliest record of the existence of coal in Alabama was made in 1834. The first statement of production in the State is contained in the United States census report for 1840, in which year the production is given as 946 tons. The census report for 1850 does not mention any coal production for the State, and the next authentic record is contained in the census statistics of 1860, when Alabama is credited with an output of 10,200 short tons. The mines of Alabama were probably worked to a considerable extent during the Civil War, but there are no records of the actual production until 1870, for which year the United States census reports a production of 11,000 tons. Ten years later the production had increased to 323,972 short tons, but the development of the present great industry really began in 1881 and 1882, when attention was directed to the large iron deposits near the city of Birmingham and thus the great "boom" of that city and vicinity was inaugurated. By 1885 the coal production of the State had increased to nearly 2,500,000 tons. Then followed a period of relapse and liquidation, which lasted two years, after which business settled down to a conservative and rational basis and has since developed steadily. In 1902 the coal production of the State reached a total of more than 10,000,000 tons, and reached the maximum of 17,678,522 tons in 1913.

PRODUCTION.

Total production in 1914, 15,593,422 short tons; spot value, $20,849,919.

The coal production of Alabama decreased 2,085,100 tons, or 11.8 per cent, in quantity and $2,233,805, or 9.68 per cent, in value in 1914, compared with 1913. The decrease was general throughout the State, only a few counties showing a slight increase. The decrease is attributed to a number of causes, the principal one being the general business depression, which was felt particularly in Alabama because of its importance as an iron-making State, and because the iron interests more than any other branch of the mining industry suffered from the unsatisfactory trade condition. In addition to the demoralization in the iron trade, the disturbed situation in Mexico, resulted in a loss of market for Alabama coke. Alabama coal was also affected by the low price of petroleum in the Southwestern States; by increased water-power development; by the competition of coal from Kentucky and Illinois in the markets of Louisiana and Mississippi, which are normally supplied by Alabama; and by the smaller bunker trade resulting from the cessation of exports of cotton after the declaration of war in Europe. There was a plentiful supply of labor for coal-mining operations throughout the year, and no shortage of cars for transportation and no serious labor troubles were reported.

The average output of coal per man showed a decrease from 720 tons in 1913 to 649 tons in 1914, but there was a slight increase in the average output per man per day, from 2.82 tons in 1913 to 2.87 tons in 1914. The number of men employed in 1914 was 24,042, who worked an average of 226 days in the year, as compared with 24,552 men in 1913, who worked 255 days. There was a considerable increase in the quantity and percentage of coal mined by machines. In 1914 the machine-mined output increased from 4,124,301 tons, or 23.3 per cent, in 1913, to 4,937.222 tons, or 31.7 per cent. The number of machines in use, however, decreased from a total of 377 in 1913 to 362 in 1914. Of the latter, 223 were punchers, 88 short wall, 31 chain breast, and 20 long wall. The powder-mined coal in 1914 amounted to 5,498,988 tons, or 35.3 per cent, a marked decrease from the record of 1913, when more than 7,000,000 tons, or almost 40 per cent of the total, was shot off the solid. Hand-mined coal decreased from 6,315,787 tons, or 35.7 per cent. in 1913, to 5,134,787 tons, or 32.9 per cent, in 1914.

The total time lost by strikes in 1914 was 3,940 days, 320 men being idle for an average of 12 days.

About one-half of the coal mined in Alabama in 1914 was washed before being marketed or used in the manufacture of coke. The quantity of washed coal was 7,913,030 tons, yielding 7,081,868 tons of cleaned coal and 831,162 tons of waste.

The statistics of fatal accidents compiled by the Bureau of Mines show that 128 men were killed in the coal-mining operations of Alabama in 1914, all but one underground. Fifty-three of the fatalities were due to falls of roof, 37 to gas explosions and burning gas, 11 to shocks or burns caused by contact with electric wires, and 24 to haulage-way accidents. The death rate per thousand in 1914 was 5.3 against 5 in 1913, and the number of tons mined for each life lost was 121,823, against 142,569 in 1913.

The statistics of production of coal in Alabama in 1913 and 1914, with the distribution of the product for consumption, are shown in the following table:

Production of coal in Alabama in 1913 and 1914, by counties, in short tons.

1913.

County.	Loaded at mines for shipment	Sold to local trade and used by employees	Used at mines for steam and heat	Made into coke at mines	Total quantity	Total value	Average value per ton	Average number of days active	Average number of employees
Bibb	1,802,243	9,214	99,569	....	1,911,026	$2,979,240	$1.56	274	3,158
Blount	174,580	2,758	1,620	....	178,958	236,448	1.32	203	354
Etowah	135,815	725	1,252	....	137,792	171,600	1.25	256	209
Jefferson	7,149,844	83,353	412,891	1,382,746	9,028,834	11,790,737	1.31	266	11,643
St. Clair	861,579	2,909	25,891	....	890,379	1,150,457	1.29	277	798
Shelby	457,313	4,469	35,787	....	497,569	862,783	1.73	257	850
Tuscaloosa	699,690	13,891	68,836	134,888	917,305	1,172,227	1.28	271	1,183
Walker	3,671,708	42,809	101,760	150,986	3,967,263	4,481,373	1.13	223	6,031
Winston	24,841	60	50	....	24,951	36,724	1.47	228	67
Other counties*	116,423	2,162	5,030	....	123,615	200,059	1.62	233	259
Small mines	....	830	....	....	830	2,076	2.50	....	......
Total	15,094,036	163,180	752,686	1,668,620	17,678,522	23,083,724	1.31	255	24,552

*Cullman, Jackson and Marion.

1914.

Bibb	1,565,660	9,180	100,006	....	1,674,846	$2,576,057	$1.54	242	2,986
Blount	147,640	1,300	1,444	....	150,384	188,235	1.25	163	348
Etowah	153,402	1,293	2,214	....	156,909	222,239	1.42	241	279
Jefferson	6,515,079	46,527	292,071	1,082,468	7,936,145	10,486,552	1.32	236	11,343
St. Clair	726,132	1,816	24,640	....	752,588	978,196	1.30	229	896
Shelby	467,456	3,916	27,542	....	498,914	927,442	1.86	239	936
Tuscaloosa	428,387	13,355	59,562	357,595	858,899	1,177,473	1.37	226	1,491
Walker	3,037,567	51,284	112,704	248,630	3,450,185	4,124,363	1.20	199	5,416
Winston	31,035	525	58	....	31,618	46,787	1.48	248	101
Other Counties*	73,496	1,704	5,841	....	81,041	119,496	1.47	187	246
Small mines	....	1,893	....	....	1,893	3,079	1.63	....	......
Total	13,145,854	132,793	626,082	1,688,698	15,593,422	20,849,919	1.34	226	24,042

*Cullman, Jackson, and Marion.

In the following table is presented a statement of the production of coal in Alabama, by counties, during the last five years, with increase and decrease in 1914 as compared with 1913:

Production of coal in Alabama, 1910-1914, by counties, in short tons.

County.	1910	1911	1912	1913	1914	Increase (+) or decrease (—), 1914.
Bibb	1,580,564	1,633,197	1,781,335	1,911,026	1,674,846	— 236,180
Blount						
Cullman	*235,456	*210,070	*276,429	*300,092	*228,146	— 71,946
Etowah	172,465	255,860	171,308	137,792	156,909	+ 19,117
Jefferson	8,298,702	7,776,390	8,174,849	9,028,834	7,936,145	— 1,092,689
St. Clair	428,409	529,211	749,753	890,379	752,588	— 137,791
Shelby	488,141	463,089	496,949	497,569	498,914	+ 1,345
Tuscaloosa	1,081,219	1,031,658	880,967	917,305	858,899	— 58,406
Walker	3,788,479	3,103,595	3,547,962	3,967,263	3,450,185	— 517,078
Winston	16,442	16,424	18,730	24,951	31,618	+ 6,667
Other counties and small mines	21,585	1,927	2,318	3,311	5,172	+ 1,861
Total	16,111,462	15,021,421	16,100,600	17,678,522	15,593,422	— 2,085,100
Total value	$20,236,853	$19,079,949	$20,829,252	$23,083,724	$20,849,919	—$2,233,805

*Includes production of Marion County.

The statistics of production in Alabama from 1840 to the close of 1914 are shown in the following table:

Production of coal in Alabama from 1840 to 1914, in short tons.

Year	Quantity	Year	Quantity	Year	Quantity	Year	Quantity
1840	946	1860	10,200	1880	323,972	1900	8,394,275
1841	1,000	1861	10,000	1881	420,000	1901	9,099,052
1842	1,000	1862	12,500	1882	896,000	1902	10,354,570
1843	1,200	1863	15,000	1883	1,568,000	1903	11,654,324
1844	1,200	1864	15,000	1884	2,240,000	1904	11,262,046
1845	1,500	1865	12,000	1885	2,492,000	1905	11,866,069
1846	1,500	1866	12,000	1886	1,800,000	1906	13,107,963
1847	2,000	1867	10,000	1887	1,950,000	1907	14,250,454
1848	2,000	1868	10,000	1888	2,900,000	1908	11,604,593
1849	2,500	1869	10,000	1889	3,572,983	1909	13,703,450
1850	2,500	1870	11,000	1890	4,090,409	1910	16,111,462
1851	3,000	1871	15,000	1891	4,759,781	1911	15,021,421
1852	3,000	1872	16,800	1892	5,529,312	1912	16,100,600
1853	4,000	1873	44,800	1893	5,136,935	1913	17,678,522
1854	4,500	1874	50,400	1894	4,397,178	1914	15,593,422
1855	6,000	1875	67,200	1895	5,693,775		
1856	6,800	1876	112,000	1896	5,748,697	Total	270,547,780
1857	8,000	1877	196,000	1897	5,893,770		
1858	8,500	1878	224,000	1898	6,535,283		
1859	9,000	1879	280,000	1899	7,593,416		

The following tables give other details concerning the coal production in Alabama, including rank of the first ten coal producing states; production by classes of mines; labor statistics; strikes and supensions; machines used; methods of mining, etc.

Rank of first ten coal-producing States in 1913 and 1914, with quantity and value of products and percentage of each.

1913.

Production				Value			
Rank	State or Territory	Quantity (short tons)	Percentage of total product'n	Rank	State or Territory	Value	Percentage of total value
1	Pennsylvania:			1	Pennsylvania:		
	Anthracite	91,524,922	16.1		Anthracite	$195,181,127	25.7
	Bituminous	173,781,217	30.5		Bituminous	193,039,806	25.4
2	West Virginia	71,254,136	12.5	2	West Virginia	71,872,165	9.5
3	Illinois	61,618,744	10.8	3	Illinois	70,313,605	9.2
4	Ohio	36,200,527	6.3	4	Ohio	39,948,058	5.3
5	Kentucky	19,616,600	3.4	5	Alabama	23,083,724	3.0
6	Alabama	17,678,522	3.1	6	Kentucky	20,516,749	2.7
7	Indiana	17,165,671	3.0	7	Indiana	19,001,881	2.5
8	Colorado	9,232,510	1.6	8	Colorado	14,035,090	1.8
9	Virginia	8,828,068	1.5	9	Iowa	13,496,710	1.8
10	Iowa	7,525,936	1.3	10	Kansas	12,036,292	1.6

1914.

Rank	State or Territory	Quantity (short tons)	Percentage of total product'n	Rank	State or Territory	Value	Percentage of total value
1	Pennsylvania:			1	Pennsylvania:		
	Anthracite	90,821,507	17.7		Anthracite	$188,181,399	27.6
	Bituminous	147,983,294	28.8		Bituminous	159,006,296	23.3
2	West Virginia	71,707,626	14.0	2	West Virginia	71,391,408	10.5
3	Illinois	57,589,197	11.2	3	Illinois	64,693,529	9.5
4	Kentucky	20,382,763	4.0	4	Ohio	21,250,642	3.1
5	Ohio	18,843,115	4.0	5	Kentucky	20,852,463	3.0
6	Indiana	16,641,182	3.2	6	Alabama	20,849,919	3.0
7	Alabama	15,593,422	3.0	7	Indiana	18,290,928	2.7
8	Colorado	8,170,559	1.6	8	Colorado	13,601,718	2.0
9	Virginia	7,959,535	1.5	9	Iowa	13,364,070	2.0
10	Iowa	7,451,022	1.4	10	Kansas	11,238,253	1.6

Production of coal in Alabama in 1913 and 1914, according to classes of mines, in short tons.

1913.

	Mines		Production		
	Number	Percentage	Total	Average	Per Mine
First Class: (Mines producing over 200,000 tons)	19	8.5	6,112,051	321,687	34.6
Second Class: (Mines producing from 100,000 to 200,000 tons)	42	18.7	5,862,478	139,583	33.2
Third Class: (Mines producing from 50,000 to 100,000 tons)	44	19.6	3,121,545	70,944	17.6
Fourth Class: (Mines producing from 10,000 to 50,000 tons)	94	42.0	2,448,122	26,044	13.8
Fifth Class: (Mines producing less than 10,000 tons)	25	11.2	133,496	5,340	0.8
Total	224	....	17,677,692	78,918	....

1914.

	Mines		Production		
	Number	Percentage	Total	Average	Per Mine
First Class: (Mines producing over 200,000 tons)	15	7.2	4,995,244	333,016	32.1
Second Class: (Mines producing 100,000 to 200,000 tons)	37	17.9	4,851,555	131,123	31.1
Third Class: (Mines producing 50,000 to 100,000 tons)	49	23.7	3,617,972	73,836	23.2
Fourth Class: (Mines producing 10,000 to 50,000 tons)	80	38.7	2,014,766	25,185	12.9
Fifth Class: (Mines producing less than 10,000 tons)	26	12.5	111,992	4,307	.7
Total	207		15,591,529	75,321	

LABOR STATISTICS.

Statistics of labor employed in coal mines of Alabama 1908-1914.

Year	Number of days active	Average Number Employed
1908	222	19,197
1910	249	22,210
1911	227	22,707
1912	245	22,618
1913	255	24,552
1914	226	24,042

Average production per man compared with hours worked per day, and average number of days worked 1910-1914.

Year	8 hours		9 hours		10 hours		All others	Total	Days Worked	Average Tonnage	
	Mines	Men	Mines	Men	Mines	Men	Men	Men		Per Year	Per Day
1910	18	766	36	2,633	134	17,306	1,525	22,230	249	725	2.91
1911	15	550	50	5,345	102	12,628	4,184	22,707	227	662	2.92
1912	11	338	46	4,145	107	13,938	4,192	22,613	245	712	2.91
1913	13	420	36	2,496	135	18,185	3,451	24,552	255	720	2.82
1914	14	646	24	3,546	150	18,115	1,735	24,042	226	648	2.87

Statistics of labor strikes in the coal mines of Alabama in 1913 and 1914.

1913			1914		
Number of men on strike	Total days lost	Average number of days lost per man	Number of men on strike	Total days lost	Average number of days lost per man
1,048	27,041	26	320	3,940	12

MACHINES USED AND METHODS OF MINING.

Number and kind of machines in use in Alabama in 1913 and 1914.

Year	Pick	Chain Breast	Long Wall	Short Wall	Total
1913	249	42	20	66	377
1914	228	31	20	88	362

Bituminous coal mined by machines in Alabama in 1913 and 1914.

Year	Number of machines in use	Number of tons mined by machines	Total tonnage of Alabama	Percentage of total product mined by machines
1913	377	4,124,301	17,678,522	23.3
1914	362	4,937,222	15,598,422	31.66

Quantity and percentage of coal mined by different methods in Alabama in 1913 and 1914, short tons.

Year	Mined by hand	Percentage	Shot off the solid	Percentage	Mined by machines	Percentage	Not reported	Percentage	Total production
1913	6,315,787	35.7	7,052,234	39.9	4,124,301	23.3	186,200	1.1	17,678,522
1914	5,134,787	32.9	5,498,988	35.3	4,937,222	31.7	22,425	.14	15,598,422

COAL WASHING OPERATIONS.

Coal washed at the mines in Alabama in 1913 and 1914, with quantity of washed coal and of refuse obtained from it, short tons.

Year	Quantity of coal washed	Quantity of cleaned coal	Quantity of refuse
1913	8,149,082	7,210,588	938,494
1914	7,913,030	7,081,868	831,162

AVERAGE VALUE OF ALABAMA COAL.

Average value per short ton for coal at the mines in Alabama since 1908.

1908	1909	1910	1911	1912	1913	1914	Advance in 1914
$1.26	$1.19	$1.26	$1.27	$1.29	$1.31	$1.34	$0.03

COKE.

C. E. LESHER.

THE production of coke in Alabama decreased from 3,323,664 short tons, valued at $9,627,170, in 1913 to 3,084,149 tons, valued at $8,408,443, in 1914. The decrease was 239,515 tons, or 7 per cent, in quantity and $1,218,727, or 12.7 per cent, in value. There were in Alabama 4 retort-oven establishments with a total of 750 ovens, and in 1914 these 4 establishments produced 2,031,535 tons, or nearly 66 per cent of the total output, whereas 16 active beehive plants with an aggregate of 2,562 ovens in blast produced 1,052,614 tons, or a little more than 34 per cent of the total. The average production per oven in the by-product plants was 2,700 tons and the average production from active beehive ovens was 411 tons. The increase in the production of by-product coke in 1914 over 1913 was 8,576 tons, or 0.4 per cent, and the decrease in the production of beehive coke was 248,091 tons, or 18.3 per cent. The value of the by-product coke, however, showed a decrease of $147,117, or 2.8 per cent, a little over 10 per cent of the total decrease in the State. The average yield of coal in coke from the retort ovens was 69.8 per cent, and the average yield in the beehive ovens was 59.5 per cent. There is not the marked difference in the values of retort and beehive cokes (and in favor of the former) in Alabama as is shown in some States, for in Alabama the retort ovens, like the beehive, are located near the mines, and the two in that respect are somewhat on a parity, whereas in most of the States in which retort coke is made the ovens are at considerable distances from the mines, and the transportation charges assessed against the coal appear in the cost of the coke to the consumer. In fact, the Alabama beehive coke had a higher value per ton in 1914 than the retort coke, the average being $3.16 for beehive and $2.50 for retort coke. The explanation of this seeming inconsistency lies in the fact that all of the retort coke is used by the producers in their own furnaces, and the coke is charged to the furnaces at little more than cost, whereas the greater part of the beehive product is commercial coke, some of it for foundry use, and profits are included in the value.

That the beehive oven has had its day in Alabama and is on the decline is evidenced by the fact that no new ovens of that type have been built in the last five years, and that 18 establishments with a complement of 5,015 ovens out of a total of 34 establishments with 8,535 ovens were idle in 1914, not counting the idle ovens at plants producing some coke in 1914. There were fewer beehive ovens in existence in Alabama in 1914 than in 1908, six years before. The number of retort ovens increased from 620 in 1912 and 700 in 1913 to 750 in 1914. The 750 completed ovens included 300 Semet-Solvay and 450 Koppers ovens. There were no new ovens under construction in Alabama at the close of 1914, and 8 establishments with a total of 1,047 beehive ovens were abandoned during the year.

The production of coke in Alabama in 1880, 1890, 1900, and annually from 1910 to 1914, is shown in the following table:

Statistics of the manufacture of coke in Alabama, 1880-1914.

Year	Establishments	Ovens		Coal used (short tons)	Yield of coal in coke (per cent)	Coke produced (short tons)	Total value of coke at ovens	Value of coke at ovens, per ton
		Built	Building					
1880	4	316	100	106,283	57.0	60,781	$183,063	$3.01
1890	20	4,805	371	1,809,964	59.0	1,072,942	2,589,447	2.41
1900	30	6,529	690	3,582,547	58.9	2,110,837	5,629,423	2.67
1910	43	10,132	340	5,272,322	61.6	3,249,027	9,165,821	2.82
1911	44	10,121	280	4,411,298	62.6	2,761,521	7,593,594	2.75
1912	46	10,208	100	4,585,498	64.9	2,975,489	8,098,412	2.72
1913	46	10,284	20	5,218,323	63.6	3,323,664	9,627,170	2.90
1914	38	*9,285	0	4,678,196	65.9	3,084,149	8,408,443	2.73

*Includes 300 Semet-Solvay and 450 Koppers ovens.

Almost 85 per cent of the coal used in the manufacture of coke in Alabama is washed before being charged into the ovens. In 1914. out of a total of 4,678,196 tons of coal make into coke, 3,974,955 were washed. Of the washed coal used 1,905,317 tons were slack and 2,069,638 were mine run. The unwashed mine-run coal used was 703,241 tons. No unwashed slack was used in 1914.

The character of the coal used in the manufacture of coke in Alabama in 1890, 1900, and for the last five years is shown in the following table:

Character of coal used in the manufacture of coke in Alabama, 1890-1914, in short tons.

Year	Run of Mine		Slack		Total
	Unwashed	Washed	Unwashed	Washed	
1890	1,480,669	0	206,106	123,189	1,809,964
1900	1,729,882	152,077	165,418	1,535,170	3,582,547
1910	771,931	1,308,085	0	3,192,306	5,272,322
1911	693,135	1,295,109	2,937	2,420,117	4,411,298
1912	747,305	896,421	18,793	2,922,979	4,585,498
1913	868,659	684,223	0	3,665,441	5,218,323
1914	703,241	2,069,638	0	1,905,317	4,678,196

RANK OF COKE-PRODUCING STATES.

The record of the production of coke in 1914 effected several changes in relative importance of the States in connection with the industry. Illinois superseded West Virginia as fourth in rank, but with that exception the first seven States held the same position in 1914 as in 1913. Pennsylvania of course stands preeminently first, with Alabama second, and Indiana third. West Virgina was fifth in 1914, but if all of the coke made from West Virginia coal were produced in that State it would be well fixed in second place, as by far the larger part of the coke manufactured in Ohio, Indiana, and Illinois is from West Virginia coal. As, however, the production of coke in retort ovens at or near the points of consumption is likely to continue to increase in greater proportion and the beehive ovens to disappear gradually from the mining regions, it is not probable that West Virginia will again assume its former importance as a coke-producing State. The quantity of coke made in West Virginia in 1913 was less than one-half of that made from West Virginia coal in ovens outside the State.

Among the less important States Wisconsin moved up from ninth to eighth place, Michigan from eleventh to ninth, Ohio from fourteenth to eleventh, and Tennessee was replaced by Kentucky, which moved from sixteenth to thirteenth place. New York, eighth in rank in 1913, fell to twelfth in 1914. The positions held by the coke-producing States are shown in the following table:

Rank of the States in production of coke, 1910-1914.

State	1910	1911	1912	1913	1914	State	1910	1911	1912	1913	1914
Pennsylvania	1	1	1	1	1	Kentucky	20	19	18	16	13
Alabama	3	2	2	2	2	New Mexico	10	11	12	12	14
Indiana	17	6	3	3	3	Utah	16	17	15	15	15
Illinois	4	4	5	5	4	Tennessee	13	14	14	13	16
West Virginia	2	3	4	4	5	New Jersey	15	16	17	17	17
Virginia	5	7	7	6	6	Minnesota	18	18	19	19	18
Colorado	6	5	6	7	7	Maryland	12	13	16	18	19
Wisconsin	8	9	9	9	8	Washington	19	20	20	20	20
Michigan	11	12	11	11	9	Georgia	21	21	21	21	21
Massachusetts	9	10	10	10	10	Kansas	24	22	22	......	......
Ohio	14	15	13	14	11	Montana	22	......	......	......	......
New York	7	8	8	8	12	Oklahoma	23	......	......	......	......

Comparison of the production and value of coke in Alabama in 1913 and 1914.

	Number of ovens	Coal charged (short tons)	Coke produced (short tons)	Total value of coke at ovens	Percentage of total U. S. value
1913	10,284	5,218,323	3,323,664	$9,627,170	7.46
1914	9,285	4,678,196	3,084,149	8,408,443	9.52
Decrease	999	540,127	289,515	1,218,727	......
Percentage	9.71	10.36	7.2	12.66	......

Quantity and value of coal used in the manufacture of coke in Alabama in 1913 and 1914, and quantity and value of same per ton of coke.

Year	Coal used (short tons)	Total value of coal	Value of coal per ton	Quantity of coal per ton of coke (short tons)	Value of coal to a ton of coke
1913	5,218,323	$7,609,963	$1.46	1.570	$2.292
1914	4,678,196	6,765,639	1.45	1.517	2.200

Character of coal used in the manufacture of coke in Alabama in 1913 and 1914, in short tons.

Year	Run of Mine		Slack		Total			
	Unwashed	Washed	Unwashed	Washed	Unwashed	Percentage	Washed	Percentage
1913	868,659	684,223	0	3,665,441	868,659	16.6	4,349,664	83.4
1914	703,241	2,069,638	0	1,905,317	703,241	15.0	3,974,955	85.0

Statistics of the production of coke in beehive and retort ovens in Alabama, 1913 and 1914.

Year	Beehive Coke		By-product Coke		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1913	1,300,705	$4,401,216	2,022,959	$5,225,954	3,323,664	$9,627,170
1914	1,052,614	3,329,606	2,031,535	5,078,837	3,084,149	8,408,443

Record of by-product ovens in Alabama, 1910-1914.

Year	Built	Building
December 31, 1910	280	340
December 31, 1911	340	280
December 31, 1912	620*	100
December 31, 1913	700	20
December 31, 1914	750	0

Complete list of retort coke-oven plants of Alabama, Jan. 1, 1915.

Town	System	Name of company owning plant	Number of installments	Date put in operation	Number of ovens	Uses of coke	Uses of surplus gas
Ensley (near Birmingham)	Semet-Solvay	Tennessee Coal, Iron & R. R. Co.	First	October, 1898	120	Blast furnace	Fuel
			Second	March, 1902	120	Blast furnace	Fuel
Tuscaloosa	Semet-Solvay	Central Iron & Coal Co.	First	February, 1906	40	Blast furnace	Fuel
Tuscaloosa	Semet-Solvay	Central Iron & Coal Co.	Second	1914	20	Blast furnace	Fuel
Woodward	Koppers	Woodward Iron Co.	First	1911	60	Blast furnace	Fuel and power
Woodward	Koppers	Woodward Iron Co.	Second	1913	80	Blast furnace	Fuel and power
Woodward	Koppers	Woodward Iron Co.	Third	1914	30	Blast furnace	Fuel and power
Fairfield	Koppers	Tennessee Coal, Iron & R. R. Co.	First	1912	280	Blast furnace	Fuel and power

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GOLD AND SILVER.

J. P. Dunlop.

THERE does not appear to be any record of the first mining in Alabama, but it probably dates from about 1830 or shortly after the gold excitement commenced in Georgia. The estimated production up to 1879 was $365,300, and the yearly output from 1880 to 1903 varied from $1,000 to $8,000 a year. Alabama, unlike most other Southern States, has made its greatest production in recent years from 1904 to 1910, from deep mines, including the Hog Mountain in Tallapoosa County and the Storey in Talladega County. The estimated total yield of gold from Alabama to the end of 1914 is $749,384.

The mine production of gold in Alabama in 1914 was $11,970, against $11,094 in 1913, and the by-product of silver was 199 fine ounces against 117 ounces in 1913. The total value of the production of precious metals was $12,080, against $11,165 in 1913. No copper, lead, or zinc production has been reported from Alabama in recent years.

The following table shows the mine production of gold, silver, and copper in Alabama since 1905, when the United States Geological Survey first collected detailed figures from the mines of the Eastern States:

Tonnage of ore treated and output of metals in Alabama, 1905-1914.

Year	Ore sold or treated Short tons	Gold*	Silver* Fine ounces	Copper Pounds	Total value
1905	16,425	$41,530	336	....	$41,733
1906	8,565	24,921	124	....	25,004
1907	18,400	25,982	439	84.678	43,208
1908	11,174	41,208	282	....	41,357
1909	9,886	29,239	212	....	29,349
1910	9,763	33,538	268	....	33,678
1911	6,360	18,916	171	....	19,007
1912	5,693	16,724	168	....	16,827
1913	4,068	11,094	117	....	11,165
1914	5,079	11,970	199	....	12,080
Increase in 1914	1,011	876	82	....	915
Percentage	24.85	7.89	70.08	....	81.97

*Includes placer gold and silver.

The production for 1914 was mainly from 5,079 short tons of siliceous ore, with an average recoverable value in gold and silver of $2.28 a ton, against 4,068 tons and an average recovery of $2.74 in 1913, and 5,693 tons and an average recovery of $2.96 in 1912. The only placer gold reported was a small quantity obtained by the Clear Creek Gold Mining Co., from the Arbacoochee placers, in Cleburne County. These placers were worked experimentally by means of a small dredge from May until December, when the plant was dismantled.

In Clay County, near Pyriton, are several pyrite mines, all idle in 1913 and 1914, whose ores, formerly sold for their sulphur content, produced residues containing gold, silver and copper. It is reported that the property of the Southern Mineral Development Co. at Pyriton, contains a large deposit of crystalline granular pyrite capable of producing first-class ore for acid manufacture, but that its development awaits a market for the ore. One assay in 1914 is reported to show a content of 5.20 per cent of copper and of $1.60 in gold per ton of the ore.

At the Storey mine, near Waldo, in Talladega County, now owned by the Gold Log Mining Co., a considerable quantity of ore was treated in a 10-ton-5-stamp mill, by amalgamation. The ore is siliceous and occurs in veins and lenses in the metamorphic schists. The mine and the mill were operated intermittently during the year, and considerable development was accomplished.

At the Hog Mountain mine, near Alexander City, in Tallapoosa County, an increased tonnage was treated in a 100-ton cyanidation and blanket-concentration plant, after crushing in rolls and tube mill. Concentrates made contained about 6.2 per cent of bismuth, but this was not paid for by the purchasers. The greater part of the ore treated was unoxidized, but a portion was from the oxidized zone, which extends from 40 to 60 feet from the surface. The veins are of quartz in intrusive granite, and a little pyrrhotite is reported present. The quantity of gold recovered by means of cyanidation was slightly in excess of that derived from concentrates, and most of the small yield of silver was derived from the concentrates shipped.

The old mine of the Dutch Bend Mining Co., also near Alexander City, which is equipped with a 20-stamp mill, was still idle because of litigation.

GRAPHITE.

EDSON S. BASTIN.

THREE firms produced graphite in Alabama in 1914. They were the Quenelda Graphite Company, and the Alabama Graphite Company in Clay County, and the Flaketown Graphite Company in Chilton County.

The last firm installed early in the year a Huff electrostatic separator for the final refining of the flake graphite, with a view especially to the elimination of admixed mica.

According to H. B. Johnson, who installed the electrostatic equipment, the product obtained ran over 94 per cent carbon in carload lots. As this process avoids the use of buhrstone mills, practically no graphite dust is produced, all the product being coarser than 60 mesh. The "dust" brings comparatively small prices, hence the economy effected in this particular is important.

About December 1 a new company, the Jennings Graphite Company, with office at Lineville in Clay County, began the mining of graphite about three miles north of Ashland.

Production and value of crystalline graphite in 1913 and 1914.

	Quantity Pounds	Value	Percentage of total U. S. Quantity	Percentage of total U. S. Value
1913	2,020,910	$87,336	29.78	29.73
1914	2,410,200	118,000	27.79	*36.41
Increase	389,290	31,336		
Percentage	19.26	35.88		

*This is Alabama's proportion of the total U. S. value of graphite (amorphous and crystalline), while Alabama's production in 1914 represents 41.35 per cent of the total U. S. value of crystalline graphite.

For extended notes on the Alabama graphite occurrences, those interested are referred to the section on Graphite by Mr. E. S. Bastin, in Bulletin No. 15 of the Geological Survey of Alabama.—E. A. S.

IRON ORE.

EUGENE A. SMITH.

IRON ores of Alabama in the order of their economic importance are (1) red ore or hematite; (2) the brown ore or limonite; (3) the gray ore. The black band and clay iron stone have been noticed as occurring in a number of places, but only the red ore and the brown ore have been mined on any large scale.

Practically all the ore mined in Alabama is smelted in the State, the shipments out of the State being about equal to those received from other states.

The tables given below will show the rank of Alabama among the States of the Union both in the production of iron ore and in pig iron.

RED ORE OR HEMATITE.

All the ore of this quality mined in Alabama occurs in the Clinton or Red Mountain formation. The Red Mountain ridges occur on each side of the anticlinal valleys which separate the coal fields. In places the red ore ridges are lacking on one side, usually the western, of the valleys, being cut out by faults, while on the other hand the ridge may be duplicated on one side of the valley by the same faults.

In most of the valley occurrences the moderate dips of the ore bed are on the eastern side and there are also practically all of the ore mines. Murphrees Valley makes an exception to this, the moderate dips and the iron mines being on the western side. The iron ore occurs mainly in the central part of the formation in seams or beds one to five in number, which vary in thickness from a few inches to thirty feet.

While the ore seams are very persistent along the outcrop which in Alabama must be as much as 50 miles, yet they vary greatly from place to place, being either too thin or too lean for profitable working in the greater part of this distance.

The most important development of the Clinton ore in this State and in the world is along the 15 or 16 miles stretch of the east Red Mountain between Birmingham and Bessemer, and there is a practically continuous series of mines and strippings for this entire distance. Much mining of this ore has also been done near Gate City, Village Springs, Attalla, Gadsden, Round Mountain, Gaylesville, Ft. Payne, Valley Head, etc.

The completion in October, 1912, of a diamond drill boring in Shades Valley, within a mile of the base of Shades Mountain, gives a definite answer to the speculations concerning the occurrence of red ore under Shades Valley. This boring shows that there is no falling off in the thickness and quality of the ore with distance from the outcrop, and that the depth of the ore below the surface at a distance of more than 2½ miles from the outcrop on Red Mountain is not too great for shaft mining.

The elevation of the surface at the drilling is 595 feet. The top of the ore was reached at a depth of 1,902 feet and a section of the seam in descending order is:

Ore (self-fluxing)	9 ft. 6 in.
Shale	4 in.
Ore (Siliceous)	9 ft. 6 in.

An analysis of an average sample of the drill core of the upper bench, made by David Hancock, shows as follows:

	Per Cent.
Metallic iron	39.51
Silica	9.94
Alumina	3.34
Calcium Carbonate	24.20
Magnesium carbonate	.78
Metallic manganese	.20
Phosphorus	.32

The importance of this demonstration of a vast increase in the amount of red ore available immediately or in the near future, cannot well be overestimated.

In 1913 the Gulf States Steel Company acquired about 1,500 acres of land upon which the drill hole above mentioned was located. They have since been sinking a double track slope to the ore, which they expect to reach about April 1, 1916. In time this is likely to be the largest producing mine in the State.

Another drill hole was put down in Shades Valley in 1913, in Section 19, T. 19, R. 3 W., but the records are not available for publication at the present time.

The hematite production of Alabama for 1914 was 3,902,567 long tons as against 4,370,823 tons, a decrease for 1914 of 468,256 tons or 10.71 per cent.

This 1914 production of hematite is 80.65 per cent of the total iron ore production of the State, and 9.42 per cent of the total iron ore production of the United States.

The average price of hematite in Alabama in 1913 was $1.18; in 1914, $1.21.

BROWN ORE OR LIMONITE.

This ore, the second in importance in the State and third in the United States, furnished only 2.26 per cent of the total iron ore production of the United States, and 19.35 per cent of the iron ore production of the State in 1914. The entire limonite production of the United States in 1914 was 1,537,750 long tons, of which Alabama contributed 936,392 tons or 60.89 per cent, and the State holds accordingly the first rank in this industry.

In the early days of iron making and up to the year 1876 this was the only ore used in the catalan forges, bloomaries, and charcoal furnaces of the State. It was then demonstrated that good iron could be made at low cost from the red ores, with coke for the fuel.

In general the limonites are considered the best of the ores of Alabama and they command the highest prices and command a ready sale.

The usual mode of occurrence is in irregular masses of concretionary origin in the residual clays resulting from the decomposition of limestones, and as a consequence the mining is uncertain and expensive. Limonite also occurs in regularly stratified seams or beds, and then it is the result of the alteration of pyrites or of carbonate ores. Practically all of the brown ore actually mined is that occurring in the residual clays above mentioned. Most of the ore before going to the furnace is washed and screened, and this manipulation, together with the cost of mining, makes it the most expensive of the iron ores, and it is therefore seldom used alone, but is usually mixed with the red ore in proportions determined by the quality of the iron desired. It is used alone in the charcoal furnaces and also in the coke furnaces when a particularly tough pig iron is wanted.

The limonite deposits are very numerous and are distributed over a broad expanse of country and in many places are known to be very extensive. In some of the deposits the ore is in nearly solid mass, in others it is much scattered, and in consequence the amount of foreign material necessary to be moved for every ton of ore produced, varies very much, not only in the different ore banks but also in the different parts of the same bank.

The deposits occur in nearly all the geological formations of the State, but in most of these the ore is either insufficient in quantity or not pure enough to be of much commercial value. The most important of the deposits, in point of extent and value, occur overlying the following formations, viz., the Knox Dolomite and the Weisner Quartzite, the Lauderdale Chert of the Lower Carboniferous, and the Lafayette. Some extensive beds of ore of inferior quality generally occur also in the Tuscaloosa formation of the Cretaceous, and in the upper part of the Lower Carboniferous and in the Metamorphic rocks.

The limonite or brown ore production of Alabama in 1914 was 936,392 long tons, as against 844,917 tons in 1913, an increase of 91,475 tons or 10.83 per cent.

The average price per long ton of brown ore marketed in Alabama in 1913 was $1.61; in 1914, $1.49.

The following tables show details concerning the production of iron ore in the State, together with the rank of the State in mined and marketed iron ore in 1913 and 1914.

Iron ore mined in Alabama in 1913 and 1914, by varieties, with percentage of increase in 1914, in long tons.

Year	Hematite	Brown Ore	Total Quantity	Percentage of total U. S. produc'n.
1913	4,370,823	844,917	5,215,740	8.42
1914	3,902,567	936,392	4,838,959	11.68
Decrease or Increase	— 468,256	+ 91,475	— 376,581	....
Percentage of Decrease or Increase in 1914	— 10.71	+ 10.83	— 7.22	....

Iron ore marketed in Alabama in 1913 and 1914, by varieties, in long tons.

Year	Hematite	Brown Ore	Total Quantity	Total Value
1913	4,488,176	845,042	5,333,218	$6,648,569
1914	3,589,809	925,117	4,514,926	5,727,619
Increase or Decrease	— 898,367	+ 80,075	— 818,292	— 920,950
Percent. of Incr'se or Decrease	20.02	9.49	15.34	13.85

Rank of first five states in mined and marketed production of iron ore in 1913 and 1914.

1913.

Rank	State	Mined		Marketed			
		Quantity (long tons)	Percentage of total production	Quantity (long tons)	Percentage of total production	Value	Percentage of total value
1	Minnesota	38,657,793	62.37	36,603,331	61.37	$80,789,025	61.72
2	Michigan	12,841,093	20.72	12,668,560	21.24	33,479,954	25.58
3	Alabama	5,215,740	8.42	5,333,218	8.94	6,648,569	5.08
4	New York	1,459,628	2.36	1,420,889	2.38	3,100,285	2.37
5	Wisconsin	1,018,272	1.64	896,243	1.50	2,149,397	1.64

1914.

Rank	State	Mined		Marketed			
		Quantity (long tons)	Percentage of total production	Quantity (long tons)	Percentage of total production	Value	Percentage of total value
1	Minnesota	21,946,901	52.96	23,298,547	58.66	$40,628,771	56.50
2	Michigan	10,796,200	26.05	8,533,280	21.49	18,722,358	26.04
3	Alabama	4,838,959	11.68	4,514,926	11.37	5,727,619	7.97
4	Wisconsin	886,512	2.13	591,595	1.49	1,178,610	1.64
5	New York	785,377	1.90	640,252	1.61	1,992,892	2.77

PRINCIPAL IRON ORE MINES.

IN 1914 there were 340 iron ore mines active in the United States as compared with 411 in 1913, and 164 mines produced more than 50,000 long tons of iron ore each, as compared with 194 mines in 1913.

The Red Mountain group of red hematite mines in the Birmingham District, Alabama, led in 1914 with an output of 2,008,465 long tons of ore, although this quantity is nearly 200,000 tons lower than the output of this group in 1913. Four of the five mines producing more than 1,000,000 tons each in 1914 are in Minnesota.

Iron ore mines of Alabama that produced more than 50,000 long tons each in 1914.

Name of Mine	Nearest Town	Variety of Ore	Quantity
1. Red Mountain Group	Bessemer	Hematite	2,008,465
2. Woodward, 1, 2, and 3	Lipscomb	Hematite	650,507
3. Raimund No. 1	Bessemer	Hematite	231,363
4. Songo	Songo	Hematite	150,732
5. Steinman	Steinman	Hematite	144,195
6. Greeley	Greeley	Brown Ore	136,289
7. Friedman	Woodstock	Brown Ore	81,556
8. Raimund No. 2	Bessemer	Hematite	77,823
9. Ironaton	Ironaton	Brown Ore	75,245
10. Houston	Rickey	Brown Ore	70,720
11. Docray	Docray	Brown Ore	67,237
12. Attalla	Attalla	Hematite	60,153
13. Tannehill	Goethite	Brown Ore	56,729
Total 13 mines			3,811,014
Unspecified* (4 mines)			861,754
Tonnage from 17 mines producing over 50,000 tons			4,672,768
Tonnage from 14 mines producing less than 50,000 tons each			166,191
Grand total of Alabama production			4,838,959

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*Includes the product of 4 mines, producing over 50,000 tons each, operated by 2 companies which do not permit the publication of individual statistics.

PIG IRON.

Quantity and value of pig iron (exclusive of ferro-alloys) marketed in the United States in 1913 and 1914 (first five states), with decrease and percentage of decrease in 1914, in long tons.

State	1913		1914		Decrease in 1914		Percentage of Decrease in 1914	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1 Pennsylvania	12,871,849	$197,726,814	9,267,197	$127,686,331	3,604,152	$70,039,983	28.00	35.42
2 Ohio	6,913,961	103,824,517	5,226,925	70,331,114	1,687,036	33,493,403	24.40	32.26
3 Illinois	2,892,263	45,796,966	1,793,714	24,382,458	1,098,549	21,414,508	37.98	46.76
4 Alabama	1,924,762	23,242,374	1,661,420	17,481,828	263,342	5,760,546	13.68	24.78
5 New York	1,967,449	30,203,673	1,357,575	19,353,809	609,874	10,850,863	31.00	35.92

Production of pig iron, (including ferro-alloys) in 1913 and 1914, (first five States), in long tons
Bureau of Statistics of American Iron & Steel Institute.

State		1913		1914	
	Rank	Quantity	Percentage	Quantity	Percentage
Pennsylvania	1	12,954,936	41.84	9,733,369	41.72
Ohio	2	7,129,525	23.02	5,283,426	22.64
Illinois	3	2,927,832	9.45	1,847,451	7.92
Alabama	4	2,057,911	6.65	1,826,929	7.83
New York and New Jersey	5	2,187,620	7.06	1,559,864	6.69

LIME.

EUGENE A. SMITH.

DURING the year 1914 there was a falling off in the production of lime in Alabama, as compared with the production of the preceding year. The total product of 12 operators in 1914, was 46,966 short tons, a decrease from the 1913 production of 28,502 short tons, or 37.77 per cent. The value of the product was $199,814, a decrease of $90,580, or 31.19 per cent.

As heretofore, the most important use of the lime produced was for building purposes. 22.57 per cent of the State's total production is definitely so credited in the returns, which, added to the 16.61 per cent in the form of hydrated lime, produced by three operators, gives 39.18 per cent definitely assigned to building purposes. Of the 66.29 per cent sold to dealers, uses not specified, a large proportion undoubtedly goes for building purposes, so that probably more than 50 per cent, possibly 75 per cent of the product is thus used. Other chief uses for lime are in chemical works, paper mills, soap factories, manufactories of sand-lime brick, slag cement, etc.

Shelby county as heretofore, was the largest producer in 1914, having produced 28,268 tons, or about 60 per cent of the total. The other producers in the order of their rank were Etowah, Blount, Jackson and DeKalb.

The following tables present some additional data on the lime production in Alabama in 1913 and 1914:

Production of lime, 1913 and 1914.

	Number of operators	Quantity (short tons)	Rank of state by quantity	Value	Rank of state by value	Average price per ton	Percentage of total U. S. value
1913	12	75,468	16	$290,394	16	$3.85	1.98
1914	12	46,966	17	199,814	18	4.25	1.51
Decrease		28,502		90,580			
Percentage		37.77		31.19			

Number of lime kilns in Alabama using various kinds of fuel in 1913 and 1914.

Year	Coal	Wood	Coal and Wood	Total Number of Kilns
1913	18	0	30	48
1914	*16	10	9	35

*8 coal and 8 gas producers.

Those interested in the subject of lime are referred to an article on lime by Ralph W. Stone of the U. S. Geological Survey, and on the Source, Manufacture, and Use of Lime, by E. F. Burchard and Warren E. Emley of the U. S. Geological Survey, published in Vol. II of the Mineral Resources of the United States for the year 1913.

MICA.

MICA mines were opened in Alabama during the early days of mica mining in the Southern States. Prospects have been tested at various subsequent times, and considerable mining has been carried on at intervals during the last 20 years. The mines are located in Randolph, Cleburne, Clay, and Tallapoosa counties, and there are prospects in Lee, Coosa, Chilton and other counties.

The mines of Randolph and Clay counties yield a very fine grade of clear "rum"-colored mica.

MINERAL WATERS.

R. B. DOLE.

RETURNS from Alabama indicate that the mineral-water trade in 1914 was much the same as in 1913. The sales amounted to 169,279 gallons, or 408 gallons less than in 1913, and the value of the output was $17,125, or $2,218 less than in 1913. The average price was 10 cents a gallon, against an average of 11 cents in 1913. The decrease in value was principally in table waters. Fourteen springs reported sales; four springs from which no reports were obtained have been considered idle. One spring idle in 1913 was active in 1914, and one spring's output which was not reported was estimated on the basis of sales in 1913. McCary Mineral Well and Talladega Springs reported sales for the first time. Six bathing establishments and 7 resorts accommodating about 1,200 guests were maintained. In addition to the quantity reported as sold, about 86,000 gallons of mineral water was used in the manufacture of soft drinks.

The following 14 springs reported sales:

Bailey Springs, Florence, Lauderdale County.
Bladon Springs, Bladon Springs, Choctaw County.
Bromberg Gulf Coast Lithia Spring, Bayou Labatre, Mobile County.
Cooks Spring, Cooks Spring, St. Clair County.
Dixie Spring, Dixie Spring, Walker County.
Ingram Lithia Well, near Ohatchee, Calhoun County.
Livingston Mineral Well, Livingston, Sumter County.
Luverne Mineral Spring, Luverne, Crenshaw County.
McCary Mineral Well, near Birmingham, Jefferson County.
Matchless Mineral Wells, east of Greenville, Butler County.
Purity Spring, Spring Hill, Mobile County.
Shocco Spring, Talladega, Talladega County.
Talladega Springs, Talladega, Talladega County.
White Sulphur Wells, near Jackson, Clarke County.

The reports of the Alabama Mineral Springs, and The McGregor Spring, were received too late for inclusion in the 1914 tabulations. Estimate on the basis of the 1913 report has been made for the McGregor Spring.

The following table shows the relative productions and their respective values of mineral and table waters, in 1913 and 1914:

Production and value of mineral and table waters sold in 1913 and 1914.

	No. of springs reporting	Quantity sold (gallons)	Average retail price	Total value of mineral waters	Percentage of total U. S. value
1913	15	169,687	0.11	$19,343	0.34
1914	15	169,279	.10	17,125	0.35
Decrease		— 408		— 2,218	
Percentage		— .24		— 11.47	

The quantity of water used in the manufacture of "soft drinks" in 1913 was 70,000 gallons; in 1914, 86,500 gallons.

NATURAL GAS.

JOHN D. NORTHROP.

THE commercial production of natural gas in Alabama is limited to Madison, Walker, and Fayette counties, in the northern part of the State, the gas produced being supplied to some 395 domestic and 2 industrial consumers in West Huntsville, Jasper, and Fayette. Compared with 1913, the number of consumers supplied with gas in 1914 was increased by 57, and the income derived from the sale of gas was proportionately increased.

In Winston County, also, in the northern part of the State, a small quantity of natural gas produced from a single well was utilized in the field for drilling.

The small gas field in Fayette County is located in the western part of the Warrior coal field and obtains its production from sandstone layers in the lower part of the Pennsylvanian series of the Carboniferous system.

Two productive gas wells were completed in Alabama in 1914 and 4 exhausted wells were abandoned, there being 16 active gas wells in the State at the end of the year.

Because of the small number of producers, the statistics of production and consumption of natural gas in Alabama cannot be given, without revealing confidential data furnished by individual companies.

OCHER.

JAMES M. HILL.

OCHER is a hydrated ferric oxide permeating a clay base. It has a specific gravity of about 3.5 and a decidedly golden-yellow color. As viewed under the microscope and with considerable enlargement the particles composing ocher appear flocculent and uniform. Good grades should contain 20 per cent or more of iron oxide, though there is a wide variation in the iron content of the material sold as ocher. Ferruginous shale is often ground and the product marketed as ocher, but unless the material is actually an ocher, as defined above, such product is classed under slate and shale in this chapter.

In 1913 ocher was produced in Georgia, Pennsylvania, Virginia, Alabama, California, Iowa, and Vermont, the States being named in the order of their producing importance. In 1913 Alabama re-entered the class of ocher producers, a new mine being opened in Clarke County.*

Since the beginning of the European war domestic ochers have been more used than heretofore. It is the general opinion among the users of this pigment that the domestic ocher does not compare with the French ocher in tone, color, or strength. It seems to be the case, as in many American industries, that the producers will not prepare their materials with the care used by the foreign manufacturers. It is the belief of the writer that some domestic ochers could be made equal to the French ochers in every respect if American producers would give more attention to the details of cleaning and floating. It has been said of Americans ochers† that, "by skillful handling, a thoroughly satisfactory color can be obtained. This is done by tinting the ocher with American chrome yellow until the correct shade is obtained."

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*This mine was the only producer of ocher in 1914, but there are many promising deposits of ocher in Alabama, especially in the area of the Tuscaloosa formation of the Cretaceous, as well as in other parts of the Coastal Plain southward nearly to the Gulf.—E. A. S.

†Paint, Oil, and Drug Rev., vol. 58, p. 4, Sept. 16, 1914.

SAND AND GRAVEL.

THE total production of sand and gravel in the State in 1914 was 831,430 short tons valued at $262,219, as compared with 1,405,068 tons valued at $398,088 in 1913, a decrease in quantity of 573,638 tons or 40.82 per cent, and in value of $135,869 or 34.13 per cent.

There was a decrease in the quantity of sand of 73,258 short tons or 19.44 per cent, and in value of $2,957 or 2.34 per cent.

In the quantity of gravel there was a decrease of 48.66 per cent, and in the value of 48.94 per cent.

Over 50 per cent of the sand was used for building purposes.

The following tables give a comparison of the production of sand and gravel in 1913 and 1914, and the production, value and disposition of the sand in these two years.

Production in short tons of sand and gravel in 1913 and 1914.

	Sand		Gravel		Total*		Percentage of total U. S. value
	Quantity	Value	Quantity	Value	Quantity	Value	
1913	376,797	$126,483	1,028,271	$271,605	1,405,068	$398,088	1.64
1914	303,539	123,526	527,891	138,693	831,430	262,219	1.10
Decrease	73,258	2,957	500,380	132,912	573,638	135,869	------
Percentage	19.44	2.34	48.66	48.94	40.82	34.13	------

*Chert has been added to these totals.

Production (in short tons), value and kinds of sand in 1913 and 1914.

	Molding Sand		Building Sand		Grinding and Polishing Sand		Fire Sand		Paving Sand		Engine Sand		Other Sand		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1913	57,798	$23,368	288,346	$90,347	25,903	$11,118	....	....	2,750	$1,250	....	....	2,000	$400	376,797	$126,483
1914	92,551	43,702	152,800	51,792	8,052	4,104	22,135	$6,450	5,849	$4,538	12,040	$3,127	10,112	$9,813	303,539	$123,526
Increase or Decr'se	+34,753	+20,334	−135,546	−38,555	−17,851	−7,014	....	....	+3,099	+3,288	....	....	+8,112	+9,413	−73,258	− 2,957
Percentage	60.13	87.02	47.01	42.67	68.91	36.91	....	....	112.69	263.04	....	....	405.60	2353.25	19.44	2.34

STONE.

EUGENE A. SMITH.

ON ACCOUNT of the variety of uses to which stone is put, there is no regular unit of measurement, and the figures in this report represent the values of the different varieties.

PRODUCTION.

Alabama produces only three kinds of stone, viz., limestone. marble, and sandstone.

The total value of the production of stone in Alabama showed an increase in 1914 of 2.63 per cent. The greater part of this increase was in the Limestone (rough building stone, crushed stone for road making, and concrete,) and for agricultural purposes. The sandstone also showed some increase. There was also a notable increase in the value of the marble produced. Exact figures for marble, however, cannot be given except for the year 1914, since before 1914 there were less than three producers.

The following table gives some additional details concerning the total stone production:

Total value of stone (limestone, sandstone and marble) produced in Alabama in 1914. Percentage of total U. S. value, rank of State and number of plants.

Year	Total value	Percentage of total U. S. value	Number of plants	Rank of State
1913	$1,285,944	1.54	35	20
1914	1,319,753	1.71	38	22
Increase 1914	33,809			
Percentage	2.63			

LIMESTONE.

The most important use of the limestone produced in Alabama in 1914 as in 1913 was for furnace flux, while crushed stone for road-making and concrete follow next in importance. A very decided increase in the amount of ground limestone for agricultural purposes, is to be noted.

The limestone burned into lime or used in the manufacture of Portland cement is not taken into account here, but is included in the value of each of the finished products in whose manufacture it was used.

As thus limited the total value of the limestone produced in 1914 was $787,214, as compared with $812,664 in 1913, a decrease of $25,450 or 3.13 per cent.

The value of the limestone produced in 1913 and 1914 classified according to the uses of the stone, are given in the following table:

Value of limestone (not including marble) produced in 1913 and 1914, according to uses.

Use	1913	1914	Increase (+) or Decrease (−)	Percentage
Rough Building	$9,517	$20,992	+ $11,475	+ 119.5
Dressed Building	27,020	20,558	− 6,462	− 23.9
Paving	189			
Rubble	188			
Riprap	58,850	3,882	− 54,968	− 93.4
Crushed Stone:				
Road making	47,237	75,528	+ 28,291	+ 59.9
R. R. ballast	7,187	1,076	− 6,111	− 85.0
Concrete	168,195	287,119	+ 118,924	+ 70.7
Flux	487,078	360,691	− 126,387	− 25.9
Agricultural	7,203	17,365	+ 10,165	+ 141.1
Total	812,664	787,214	− 25,450	− 3.13

LIMESTONE FOR BUILDING PURPOSES.

The preparation of cut stone for building purposes in Alabama, while on the increase, is not yet what it should be.

Practically all of this material comes from the quarries in the subcarboniferous limestone of the Tennessee Valley, the most important quarries being at Rockwood in Franklin County, operated by Foster-Creighton-Gould Co., of Nashville. This stone is quite similar in appearance, composition, and other qualities to the Indiana stone, and so far as experience in the use of the stone from the two localities in the buildings of the University of Alabama goes, the Alabama stone holds its own under influence of the weather better than does the Indiana stone. Stone steps, door sills, and window sills, buttress caps, etc., of the Alabama stone put in place in 1885 show practically no deterioration in color and wear under foot, and in crumbling and roughening under the influence of the weather, which cannot be said of some portions of the Indiana stone used in buildings erected in 1909-10. The Rockwood quarries have most modern and approved methods of machinery for sawing the stone and handling it in transit to the mills and elsewhere. The stone is of massive formation, of great thickness and extent. Blocks weighing as much as 25 tons, without crack or flaw, are not infrequently quarried, the size of the blocks being practically limited only by the capacity of the hoisting machinery.

The Oolitic variety is most extensively used for building and monumental work. It is of light gray color, uniform grain, and homogeneous texture. It possesses a quality of cheapness, it can be cut to any design required, and is at the same time strong and durable.

With the installing of adequate machinery at the quarry for doing the finished work, there should never be any longer any reason for going outside of the State for this quality of stone. Already the material has been very extensively used in public buildings in Mississippi, Tennessee, as well as in Alabama. The only reason why it was not used in the recently erected buildings at the University of Alabama was that at the time these building contracts were let, the quarries furnished only the rough sawn stone and there was not in Alabama any establishment adequately equipped for the dressing of the stone in the quantity needed.

The above statements are confirmed by a report on the comparative tests made on the Rockwood stone, and those from

Bedford, Ind., and Bowling Green, Ky., by Prof. Robert H. McNeilly, in the Engineering Laboratory of Vanderbilt University.

From this report I give the following extracts:

"GENERAL CHARACTERISTICS.—The Rockwood limestone is an almost pure oolitic limestone with frequent small crystals of calcite distributed throughout its mass. It resembles closely the Bedford stone in appearance, except that it has a slightly more open texture. The Bowling Green stone is finer in grain, softer and more easily pulverized than either the Bedford or Rockwood stones, and contains an appreciable amount of petroleum, which lends somewhat to the ease with which it is worked. In all three stones the texture is exceptionally uniform, as it is almost impossible to detect the bedding planes by eye; however in this respect the Bowling Green stone is most marked, and it is frequently necessary to test by hammer to detect which is the bed plane. Rockwood stone is lighter in color than either the Bedford or Bowling Green stones.

"CHEMICAL ANALYSIS.—The following is an analysis of the Rockwood stone made at my request by Dr. Paul C. Bowers, Chief Chemist of the Tennessee Geological Department:

	Rockwood Stone.
Moisture and loss on heating to 175° C.	0.07
Insoluble siliceous residue (SiO_2, etc.)	0.49
Oxide of Iron and Alumina (Fe_2O_3 & Al_2O_3)	0.30
Carbonate of Lime ($CaCO_3$)	98.23
Carbonate of Magnesia ($MgCO_3$)	0.97
Total	100.06

"PHYSICAL TESTS.—Comparative physical tests of the three samples of stone were made as follows:

Loss in weight on drying,
Cross bending tests,
Compression tests,
Absorption tests,
Per cent of water absorbed.
Specific gravity in bulk, and of pulverized stone,
Density,
Abrasion tests.

The results of these physical tests are summarized in the CONCLUSIONS below quoted.